AIR POLLUTION CONTROL

Report on an Inter-Regional Seminar convened by the World Health Organization in collaboration with the Government of the USSR

Moscow - Volgograd
31 August - 20 September 1967

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This report on the Inter-Regional Travelling Seminar on Air Pollution Control, held in Moscow and Volgograd from 31 August to 20 September 1967 consists of the Summary Report of the Seminar (prepared at the end of the Seminar and approved by the participants) and of extensive summaries of all the lectures delivered during the Seminar. The annexes contain the list of participants and lecturers, the timetable of the Seminar, the latest list of the USSR maximum permissible concentrations of atmospheric pollutants, and a brief description of the Sysin Institute of General and Municipal Hygiene of the USSR Academy of Medical Sciences, the leading USSR research institution in the field of air pollution. The Seminar's lectures were prepared by the staff of the Environmental Pollution Unit, Division of Environmental Health, World Health Organization, Geneva, using original typescripts as presented at the Seminar. A number of references and bibliographical notes were compiled and attached to most of the summaries as guides to further study. The ISO recommendations were followed in the transliteration of Russian names and terms.

We hope that the report will provide a useful record of the work of the Seminar. Although it has been prepared primarily for the participants of the Seminar, it might prove of wider interest since it contains much up-to-date information on air pollution activities in the USSR which is not easily accessible to those who do not read Russian.
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Summary Report of the Seminar
The Inter-Regional Travelling Seminar on Air Pollution Control, convened by the World Health Organization in collaboration with the Ministry of Health of the USSR, met in Moscow (at the Central Institute for Advanced Medical Studies) from 31 August to 4 September. The second part of the Seminar was held at Volgograd from 5 to 9 September. The final sessions were again convened in Moscow from 11 to 20 September 1967.

The major objective of this Seminar was to provide guidance for countries at present undergoing rapid industrialization and urbanization and likely to face problems of community air pollution now or in the near future. Emphasis was given to the prevention of air pollution although a number of other topics were also discussed, such as methods for setting up air quality guides, methods for measuring air pollutants, some meteorological problems in air pollution control, the epidemiology of air pollution, as well as the organizational problems involved in air pollution control.

The Seminar was attended by 18 participants from 16 Member countries.

Dr V. D. Makarov, Deputy Director of the International Health Relations Department, Ministry of Health of the USSR, welcomed the participants on behalf of his Government, and wished the Seminar every success. The Seminar was opened by Professor P. P. Ljarskij, Deputy Chief Sanitary Physician of the USSR, and by Mr R. Pavanello, Chief, Environmental Pollution, Division of Environmental Health, WHO, Geneva, on behalf of the Director-General of the World Health Organization, who expressed his thanks to the Government of the USSR for taking part in the organization of the Seminar. It was regretted that Professor V. A. Rjazanov, one of the pioneers of air pollution research in the USSR, was prevented by illness from attending the Seminar.

The programme of the Seminar comprised six major topics:

- general and organizational problems in air pollution control;
- some meteorological problems in air pollution control;
- criteria and guides to air quality;
- the monitoring and measurement of air pollution;
- the effects of air pollution on health;
- the technology of air cleaning and the prevention of air pollution from industrial sources.

Each of these topics was introduced by one or more lecturers. The introductory lectures were followed by discussion in plenary session. Informal afternoon meetings were arranged in order to allow more time for detailed discussion both of subjects included in the programme and of some other aspects of the air pollution problem. A particularly valuable feature of the Seminar was that the lectures and discussions in almost all subjects on the programme were supplemented by field visits and visits to the principal operational and research institutions engaged in air pollution in the USSR.

There were 28 lecturers and demonstrators at the Seminar, 24 of whom were USSR experts in the field of air pollution control and public health.

No permanent chairman was elected but the discussions were moderated in turn by Mr R. Pavanello, Dr V. A. Čičikov, Director of the Seminar (Central Institute for Advanced Medical Studies, Moscow), Dr K. A. Buštueva (Scientist, Environmental Pollution Unit, Division of Environmental Health, WHO, Geneva) and Professor V. B. Vouk, WHO Consultant.
GENERAL ORGANIZATIONAL PROBLEMS IN AIR POLLUTION CONTROL

WHO activities in air pollution control

Mr Pavanello reviewed and summarized the work of WHO in this field since 1955. WHO supports studies to develop methods of detection and measurement of concentrations of air pollutants; takes part in developing suitable methods for air quality and epidemiological surveys in connexion 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 other control measures for those pollutants for which adequate control does not yet exist, as well as encouraging research into all aspects of air pollution. Some research is already underway, but much still remains to be initiated or co-ordinated. Data on air pollution measurements and control will have to be systematically collected and disseminated. Training in the prevention and control of air pollution is already being provided, but increased support is essential both for existing institutions and for the creation of new ones, wherever needed.

The discussion that followed Mr Pavanello's paper clarified many aspects of WHO activity. WHO has no laboratories for the verification and comparison of data on air pollution collected in different countries, but relies on the facilities of the Member countries. There is a plan for setting up a monitoring network in Latin America and the first results are expected in the course of this year. Data collected will be processed in the WHO Zone Office in Lima. At a later stage when more elaborate treatment of data becomes necessary the results will be sent to Geneva where electronic computer facilities are available.

The work of WHO on criteria and guides for air quality was summarized by Professor Vouk. This problem will be further discussed later in this report.

Organization of air pollution control in the USSR

The organization of public health services in the USSR in relation to air pollution control was the subject of two lectures. The principal features of the organization and legislation of public health in the USSR were described by Professor Ljarskij. According to the Regulations on State Sanitary Surveillance, approved by the Council of Ministers of the USSR in October 1963, sanitary surveillance in the USSR is carried out by the Sanitary-Epidemiological Service of the USSR Ministry of Health and by the sanitary-epidemiological services of the constituent Republics. The Sanitary-Epidemiological Service is centralized and uniform throughout the country. The head of the Service is the Chief Sanitary Physician (Chief Medical Officer of Health) of the USSR; he is one of the deputy ministers of health; the Deputy Chief Sanitary Physician is the Head of the Chief Sanitary-Epidemiological Directorate in the Ministry of Health of the USSR. There is a corresponding organization in each of the constituent Republics of the USSR.

The sanitary-epidemiological station (of a republic, kraj, oblast, okrug etc.) is the basic public health institution in the USSR. It is both an organ of sanitary inspection and of public health service. The chief sanitary physicians of the corresponding administrative territories are directors of the sanitary-epidemiological stations and are, at the same time, deputy heads of the health departments of the territorial administrations. The internal organization of a sanitary-epidemiological ('sanepid') station is uniform throughout the USSR. There are three groups of departments in each 'sanepid' station: for sanitation and hygiene, for the control of epidemic diseases, and for organization and methodology. The departments of sanitation and hygiene include municipal hygiene, industrial hygiene and sanitation, nutrition hygiene and food sanitation, hygiene of children and adolescents and school sanitation. Air pollution control work is carried out in the Section for Sanitary Protection of Air of the Department of General and Municipal Hygiene and Sanitation.
The participants in the Seminar were able to become acquainted with the work of two sanitary-epidemiological stations - the Moscow City Sanitary-Epidemiological Station and the Sanitary-Epidemiological Station of Volgograd Oblast.

The role of the sanitary-epidemiological services of the USSR in the field of air pollution control was described in detail by Dr. Nedogibčenko. The organized sanitary protection of the ambient air on a nation-wide scale began in 1949. The laws for the protection of nature which have been adopted by the majority of the constituent republics constitute the legal basis for this activity. A permit issued by the sanitary-epidemiological service is needed for the operation of any plant, power station or industrial process which could be a source of air pollution. Plans and projects for the construction of new industrial enterprises or for the extension of existing ones are approved only if they satisfy the sanitary-epidemiological service. New plants emitting gaseous wastes which cannot be purified by existing technological methods must be built outside populated areas and only with the consent of the sanitary-epidemiological service. A sanitary protective zone ('green belt') has to surround any potential industrial or other major air pollution source. The width of the sanitary protective zone varies from 50 metres to 1000 metres or more, depending on the type of installation. This width may be reduced in some cases or even increased three times if the sanitary-epidemiological service considers it necessary.

The system of sanitary protective zoning was explained and demonstrated in detail to the participants during their visit to Volgograd and in particular to the new town Volžskij.

The discussion which followed these two lectures and which was resumed again during the visits to the sanitary-epidemiological stations, as well as during the informal evening discussions, concentrated on two points of considerable interest to all the participants: the setting up of legal standards for air quality in the USSR and the value of sanitary protective zoning as an air pollution control measure.

The establishment of air quality standards in the USSR is the prerogative of the Ministry of Health of the USSR, and this authority is not delegated to any other administrative body. Air quality standards are uniform throughout the USSR. Different ministries and organizations are consulted before a standard is adopted, but the Ministry of Health is the only authority to set such standards. Some participants in the Seminar found it difficult to understand how such strict standards as those in the USSR could be applicable to different parts of a country where climatic and other factors vary so widely. The opinion of the Soviet experts is that 'hygienic' standards obtained by laboratory studies do not depend on local conditions. Local conditions may make it necessary to set temporary 'sanitary' standards, and the level at which they are set is a compromise between numerous factors, including technical and economic feasibility of control as well as the health and welfare of the public. Further discussion revealed, however, that there are no sanitary standards in the USSR. There is only one set of standards, the 'hygienic' ones, adopted by the Ministry of Health of the USSR. If these standards are not attainable in the immediate vicinity of an air pollution source, a sanitary protective zone is established.

This attitude of Soviet hygienists and public health authorities seemed too restrictive to some participants in the Seminar for, while it may be good practice for the USSR to have only one set of 'hygienic' standards, it would be impossible to adopt this principle in many developing countries which need air quality guides reflecting a compromise between the social 'benefits' of industrial development and the 'damages' and 'hazards' of air pollution which necessarily accompany such development. It also emerged from the discussion that no 'emission' standards are set by the sanitary-epidemiological authorities.

With regard to zoning, there was no doubt that much can be done to reduce the air pollution problem if hygienic requirements are taken into account at the outset of city planning and development programmes. This was clearly demonstrated during the visit to the town Volžskij. However, the method of sanitary protective zoning in air pollution control is of necessity limited to countries which are not densely populated and where the cost of
land does not present a problem. On the other hand, if land is scarce zoning becomes difficult and sometimes impossible, or the width of sanitary protective zones must be greatly reduced. For such countries, air pollution abatement efforts must be directed towards the control of air pollution sources (such as removal of the source by modification of the technological process, or prevention of emission of air pollutants by purification of waste gases).

METEOROLOGICAL PROBLEMS OF AIR POLLUTION CONTROL

A problem of considerable practical importance in 'zoning' is the influence of meteorological conditions on the space and time distribution of air pollutants discharged from one or more sources. Professor Berljand explained the theoretical basis and practical application of a formula by which the maximum ground level concentration of a pollutant discharged from a number of chimneys of a given height can be calculated. There are several empirical formulae used for such calculations in the literature. The equation proposed by Professor Berljand has the advantage of having a theoretical basis; also calculations using this equation agree fairly well with observations. This formula was used as the basis for instructions for calculating the diffusion of harmful substances (dusts and $SO_2$) of industrial wastes into the atmosphere, adopted by the USSR Ministry of Health in 1963.

The application of this and other methods for different practical situations was the subject of a lively discussion.

CRITERIA AND GUIDES TO AIR QUALITY

The work of WHO on criteria and guides to air quality was briefly reviewed by Professor Vouk. He pointed out that much preliminary work for recommending internationally acceptable criteria for guides to air quality had been carried out under the auspices of WHO. The general principles on which such criteria and guides could be based have been agreed upon and endorsed by a WHO Expert Committee on Air Pollution (1963), and a guide to the selection of methods for measuring air pollutants has been prepared (1967). It remains to be seen whether general agreement among experts and scientists can be secured to establish criteria and numerical guides to air quality.

The approach of Soviet hygienists to air quality guides and standards was explained in detail in two lectures. Dr Čičikov described the methods used in the USSR for determining maximum allowable concentrations. Professor Rjazanov's lecture (read by Dr Melehina) dealt with the general principles of setting hygienic standards. According to Professor Rjazanov, the basic task of hygienists is to determine the biologically optimal environmental conditions for man. Only if the answer to this question is known, can scientifically justifiable hygienic standards be set. Consequently, standards of air quality can be determined only by studying the reaction of man and human population groups to individual pollutants, or combinations of pollutants, under various conditions. He stressed that 'hygienic' air quality standards were the optimum towards which health workers must strive, although such standards might not always be attainable. Dr Čičikov explained that in the USSR there were two indices of the degree of air pollution - the (single) maximum allowable concentration and the daily (24-hour) average concentration. The purpose of daily average standards is to prevent chronic resorptive effects of toxic substances when they are inhaled for a long time. The single maximum allowable concentration is a standard set to prevent such pollution of the ambient air which may cause reflexes by irritating the receptor of the organs of breathing, mainly the olfactory area of the nose. Both indices belong to the group of 'hygienic' standards which are the only ones recognized and adopted in the USSR. Investigations needed to establish the maximum allowable concentrations include the determination of the odour threshold and the threshold of the stimulating effect, and also the threshold of the reflex effect which is determined by pneumography, rheovasography, optical chronaxy, adaptometry and electroencephalography. Dr Čičikov also pointed out that up to the present time MAC values for 96 substances had been investigated and adopted in the USSR.
The participants in the Seminar had the opportunity of visiting the Sysin Institute of General and Municipal Hygiene of the USSR Academy of Medical Sciences, where the major part of the work on the determination of maximum allowable concentrations is carried out. Thus, they were able to acquaint themselves with many practical technical details of the methods described by Dr Čižikov.²

The problem of odour threshold was also dealt with in a lecture delivered by Professor Friberg on odour exposure and annoyance reactions from craft pulp operations. Professor Friberg described laboratory and field techniques used in Sweden for the determination of odour threshold. He pointed out that there is substantial divergence between the results obtained by different investigators; for example, the odour threshold value for methyl mercaptan is of the order of $10^{-3}$ to $10^{-7}$ mg/l and for hydrogen sulfide it is of the order of $10^{-3}$ to $10^{-6}$ mg/l. The divergence may be partly attributed to the lack of sensitivity of physical and chemical methods used for measuring the concentration so that the concentration of the substance tested has to be estimated in many cases. In spite of many drawbacks the odour threshold measurements may be of considerable practical use; as an example, he mentioned that when a craft pulp mill was recently built in Sweden, the local health authorities requested that the limit of $10^{-4}$ odour units should not be exceeded.

Criteria and guides for air quality was one of the major subjects of discussion throughout the Seminar. The participants showed much interest in examining details of experimental methods used in the USSR. Some of the questions raised concerned the reproducibility of the measurements. Statistical methods used in the determination of threshold values were also subject to discussion. It was pointed out that a double-blind technique, in which neither the subject nor the investigator knew whether pure air or odour was being offered, should be used in odour-threshold determinations. As to whether unpleasant odours should be tolerated in the ambient air, the Soviet hygienists' viewpoint is that what is pleasant is relative; what might be pleasant to one person might be excruciating to another. Any irritant or stimulant, pleasant or unpleasant, becomes intolerable if it is permanent and unavoidable, as is the case with atmospheric pollution. The biological meaning of reversible changes in the organism was another subject of discussion in connexion with studies of reflex reactions. In the USSR reflex reactions are considered as pre-adaptive reactions and as such are unacceptable from the hygienic viewpoint. Some of the participants questioned the validity of basic principles used in the determination of MPC for ambient air in the USSR. For instance, why is it assumed a priori that any reaction of the subject to the inhaled substance is harmful? From a theoretical point of view is it correct to set the maximum permissible concentrations below the levels at which neither direct nor indirect effects have been observed? Why is it assumed that the development of adaptive mechanisms should be avoided? In answer to these questions, it was stated that Soviet hygienists consider that adaptive reactions represent a physiological adjustment of the organism to changing environmental conditions. However, they point out that individuals differ in their adaptive capability and that it is practically impossible to draw a line between an adaptive and a pathological reaction. In the course of evolution man has adapted himself to many environmental factors; air pollution represents a new factor. As a rule, low concentrations of atmospheric pollutants exert a stimulating effect on the central nervous system which is not necessarily beneficial. There is a fundamental difference between air pollution and other (unpleasant or harmful) environmental factors. If the sunlight is too strong we may avoid it by drawing the curtains or by wearing dark glasses; if music is irritating we can shut it off; if we feel

² Apart from the Sysin Institute of General and Municipal Hygiene, there are many other research organizations studying problems relating to the effects of air pollution on health - the Erisman Institute of Hygiene of the RSFR, the Department of General and Municipal Hygiene of the Institute of Advanced Medical Studies, Chairs of Hygiene at medical schools, etc.
cold we can put on warm clothes; but if the air is polluted, we still cannot stop breathing. In fact man now has to adapt himself to a whole series of potentially harmful but unavoidable stresses. For instance, although vaccination demands a considerable readjustment of the organism, it is used in order to avoid an even more serious reaction - illness. Moreover, vaccination is applied to a single individual and it is possible to avoid unpleasant or harmful reactions. If all this is taken into account, it seems wrong to burden unnecessarily the adaptive mechanism of the organism by exposing it to the action of air pollutants, for the objective of hygiene is not only to preserve health but also to create optimal conditions for life, work and rest.

Some of the participants also expressed the view that field experiments under realistic conditions should be carried out when establishing criteria and setting air quality guides, and that laboratory experiments are not sufficient for this purpose. The relative frequency by which an air pollution standard can be exceeded in a given time period should be specified.

The majority of the participants agreed that it is necessary to have some criteria and guides for air quality. They should be realistic and attainable by the technological methods and financial means available, even in developing countries. Such criteria and guides should be subject to periodic revision and changed if new scientific evidence were to become available. The participants also felt international agreement on air quality criteria and guides to be highly desirable.

THE MONITORING AND MEASUREMENT OF AIR POLLUTION

The problems of sampling and measurement of air pollutants were presented in two lectures; Dr Kimina described the organization of air pollution sampling networks in the USSR, and the methodology of air pollution surveys, while the problem of standardization of analytical methods was discussed by both Dr Kimina and Mrs Manita. The main subject of Mrs Manita's lecture was, however, a review of methods used in the determination of some basic air pollutants.

It was pointed out by Dr Kimina that methods for organizing air pollution surveys in the USSR were standardized and approved by the Ministry of Health in 1962; they are now being amended and a revised edition of these instructions will be published soon. In cities where the number of air pollution sources is large and pollution of the atmosphere diffuse, systematic observations are needed and a network of stationary air pollution monitoring posts should be set up. There are 25 monitoring stations in Moscow; samples are collected for the determination of suspended matter (dust), for SO2 and for soot. Some samples are also collected for the determination of carbon monoxide and formaldehyde. Samples are collected twice weekly in the 'rajon' sampling station at a fixed time of day. In the 'city' sampling stations the samples are collected once daily at the same time each day. About 15,000 samples are collected every year. (These problems were discussed with the participants during their visit to the Moscow Sanepid Station.) The remainder of Dr Kimina's lecture was devoted to various aspects of air pollution surveys such as studies of zonal distribution of industrial effluents, the influence of meteorological conditions on air sampling results, the determination of the maximum concentration of a specific air pollutant and its distance from the air pollution source, etc. The subject of air pollution surveys was of such interest to the participants that a whole informal evening discussion was also devoted to it.

Mrs Manita reviewed the current methods used in the USSR for the determination of selected air pollutants (sulfur dioxide, nitric oxide, volatile mineral acids, carbon dioxide, ozone, and 3,4-benzpyrene). Methods used include various spectrophotometric, fluorospectrophotometric and colorimetric procedures; gas chromatography and polarography are also used extensively.

In the course of the discussion the participants were able to obtain much valuable information on technical details of analytical methods. A spectrophotometric method for
the determination of ozone attracted much attention; this method is based on the measurement of optical density at 299 m~ of ethanol solution of acridine produced by the interaction of ozone and dehydroacridine. If a sample of 10 litres of air is collected, this method makes it possible to determine 4 g of ozone per cubic metre of air. The interference of other oxidants is eliminated by taking two parallel samples. In one of these, ozone is removed by catalytic decomposition on MnO2.

With regard to the problem of standardization of methods of sampling and analysis, the participants in the Seminar agreed that:

(a) Strict international standardization of analytical methods for the determination of air pollutants is neither feasible nor desirable; it is preferable to have a set of recommended methods so that a suitable choice can be made by each laboratory depending on the facilities available.

(b) A system for laboratory inter-comparison of analytical methods and for exchange of analytical standards would be very valuable.

(c) Detailed recommendations on how to carry out an air pollution survey and how to collect systematic air pollution data are needed urgently.

The majority of the participants also agreed that the reporting of data and the basic statistical methods used in treatment of data should be uniform.

EFFECTS OF AIR POLLUTION ON HEALTH

Three lectures delivered during the Seminar dealt with different aspects of air pollution in relation to health. Dr Lawther's lecture concerned the relationship between chronic bronchitis and air pollution. Professor Šabad reviewed his work and that of other Soviet authors on air pollution as a possible factor in the etiology of lung cancer, while Professor Gol’dberg summarized different approaches and methods in the epidemiology of air pollution.

As Dr Lawther pointed out, chronic bronchitis is difficult to define. It should not be assumed that it is one disease with a single clinical picture. Chronic bronchitis may be regarded as having two phases before passing into irreversible emphysema. Simple chronic bronchitis consists of hypertrophy of the mucus-secreting elements in the bronchial mucosa leading to the hypersecretion of mucus and, clinically, to chronic cough in order to expel the mucoid sputum. Airway obstruction will be proportional to the degree of mucous hypertrophy to which will be added that produced by bronchial constriction due to irritation from other causes. There is abundant evidence that cigarette smoking is an important factor in the production of this picture. Most commonly infection supervenes, foci of bacterial growth are established, and constitutional illness results in response to the systemic infection. If the infection is not promptly eradicated, the lung parenchyma may be irreparably damaged and this, together with the airway obstruction, will eventually lead to emphysema. There is no doubt that in patients with the established disease, air pollution in higher concentrations than those observed day by day can produce worsening of the disease, sometimes fatal, by irritation of the respiratory tract.

Professor Šabad gave an account of air pollution by carcinogenic substances and of the main sources of 3,4-benzpyrene. He said that more and more data confirmed the hypothesis that cancer of the lung in man can be caused by penetration into the bronchial tract of carcinogenic substances present in the polluted air, in motor vehicle exhaust gases and in cigarette smoke. However, all this evidence would remain inconclusive unless we could induce lung cancer by carcinogenic substances. For about 40 years many research workers, including Professor Šabad, had tried to do that but without success. Only recently successful experimental results had been obtained by Soviet researchers when 7,12-dimethylbenzanthracene (DMBA) and 3,4-benzpyrene were administered to rats intratracheally as a suspension of carcinogenic substance in colloidal infusion (solution of non-anaphylactogenic
casein) with powdered china ink. The lecture concluded with a discussion of the mechanism by which 3,4-benzpyrene and other carcinogenic compounds could accumulate in the soil. There are some strains of micro-organisms in the soil which accumulate 3,4-benzpyrene and transform it by oxidation into other compounds.

Professor Gol'dberg reviewed the epidemiological studies carried out in the USSR since 1949 on the relationship between air pollution and health. The main part of this work had been carried out on groups of children, the most sensitive part of the population which had not been exposed to occupational hazards. Anthropometrical, haematological, biochemical and immunological methods, as well as clinical X-ray examinations, were used. The aim of these investigations was to detect the presence of toxic air pollutants in the organism, for instance, lead in urine and carbon monoxide in the blood; to detect specific changes linked with substances present in the polluted atmosphere, e.g. destruction of tooth enamel due to fluorides or pre-silicotic lung changes due to silica in the air; and to detect non-specific defensive adaptation to chronic exposure to low-level concentrations of toxic substances in air.

When asked whether his method for estimating sulfur dioxide was not vitiated by adsorption of the gas on filter-paper, other workers having found significant adsorption, Dr Lawther stated that experiments had shown such adsorption to produce negligible inaccuracies but he wanted to have the results mentioned during the discussion for further investigation. A question was also raised about the extent to which dust increases the toxicity of sulfur dioxide.

After thanking Professor Šabad for presenting his most important recent discoveries, Dr Lawther said that, in quoting Doll and Hill, and Hammond and Horn, it must not be forgotten that these workers and very many others had concluded that the principal cause of lung cancer was cigarette smoking. Particular interest was aroused by Professor Šabad's statement that there are micro-organisms in the soil capable of metabolizing 3,4-benzpyrene. This process has been investigated as a possible method for the purification of wastes containing 3,4-benzpyrene. Photo-oxidation of 3,4-benzpyrene was also discussed and details were requested on the method of determining 3,4-benzpyrene based on Špol'skij's effect (in liquid nitrogen). When asked whether he was careful to avoid loss of 3,4-benzpyrene when estimating its concentration in soil and vegetables by drying the samples at temperatures below which benzpyrene was volatile, Professor Šabad said that such precautions were taken.

The discussion which followed Professor Gol'dberg's paper centred on two fundamental questions: (a) Is it correct to use the most sensitive population groups in epidemiological studies? (b) Is the questionnaire method reliable? Soviet hygienists consider that their task is to protect all population groups, and if the most sensitive group is unaffected by the environmental factors under study then none of the other groups will react.

TECHNOLOGY OF AIR CLEANING AND PREVENTION OF AIR POLLUTION FROM INDUSTRIAL SOURCES

This was the central theme of the Seminar. Of a total of 24 lectures, 10 lectures and five field visits were devoted to air cleaning technology, the design and operation of air cleaning installations and their application to various industrial and power production processes.

There is a special organization in the USSR, the All-Union Association for Gas Cleaning and Dust Control (supervised and directed by the Ministry of Oil Refining and Petro-Chemistry), which deals with various aspects of research, development, design and construction of dust-removal and gas cleaning installations. It comprises a special research and development institute (NIIOGAZ); the NIIOGAZ has three branches dealing with dust removal, chemical gas cleaning and special problems of the metallurgical industry respectively. Within the All-Union Association for Gas Cleaning and Dust Control there is a special inspection service (Technical Inspectorate) which supervises and inspects the correct use of gas cleaning and dust removal devices in industry throughout the

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\( ^a \) Research Institute for Gas Cleaning.
Soviet Union. The organization of the technical inspection service and its operational activities were described in a lecture by Mr Gagarinskij and Mr Smirnov. The organization of the NIIOGAZ and its research and development programme were the subject of the lecture of Mr Uzov, who described the activities of the NIIOGAZ and reviewed current problems in the USSR of dust removal from gases in power stations, industrial heating and boiler installations; in ferrous metallurgy (open-hearth steel production, converter production, ferro-alloy plants, electric arc steel smelting furnaces); the cement industry; the production of carbon black, sulfuric acid, chemical fertilizers, and the industrial use of powder catalysts. A visit to the Semibratovo branch of NIIOGAZ proved extremely useful and instructive to all participants, who were thus able to acquaint themselves with the excellent facilities available for research into, and the development of, mechanical, electrical and filtration gas-cleaning devices. A special factory for the production of dust-removal installations is attached to this branch of NIIOGAZ.

The current status in the USSR of research, development and the industrial application of various processes and installations for chemical cleaning of industrial gases was summarized by Mrs Pitelina. The removal of sulfur dioxide is one of the main problems in this field and a large part of the lecture was devoted to various procedures for removing sulfur dioxide from industrial gases. Research into SO$_2$ removal carried out in the chemical section of NIIOGAZ concerns the catalytic oxidation of SO$_2$, the adsorption of SO$_2$ on carbonless sorbents with thermal regeneration and production of elementary sulfur; and the modification of magnesite method. The rest of the lecture dealt with the removal of hydrogen sulfide, nitric oxides, fluorides, chlorine and chlorine compounds, mercury vapour and organic mercury compounds, as well as various organic compounds.

The lectures on gas cleaning technology were supplemented by several field visits to specific industries (a lamp-black factory at Volgograd, mercury removal installations in a thermometer factory at Klin; electro-filtration installations in a Moscow thermo-power station).

Specific problems of air pollution from the burning of fossil fuel were reviewed by Dr Gil'denskjol'd while the discussion on air pollution associated with iron and steel processing was initiated by Professor Kaljušnij's lecture.

The control of air pollution from non-ferrous metallurgical plants was discussed by Mr Gordon (metallurgy of copper, lead, zinc and nickel) and by Dr Sadilova (aluminium production). Professor Friberg devoted one part of his lecture to odour control from craft pulp operations in Sweden.

Professor Varšavskij briefly outlined the efforts of the USSR automobile industry and public health authorities to reduce air pollution from motor vehicles. There are three main lines of approach in the control of air pollution from internal combustion engines: the use of tetraethyl lead has been prohibited in all large towns; catalytic combustion devices ('neutralizers') are being developed and tested, and research is proceeding into the possibility of modifying the internal combustion engine in such a way as to reduce the production of toxic and other air pollutants without reducing the mechanical efficiency of motors. Mr Zolotoyevskij spoke mainly about the possibility of expressing, quantitatively, the air polluting capability ('toxicity of the motor') of an internal combustion engine. A visit to Professor Varšavskij's laboratory was also arranged.

Lectures on technological aspects of air pollution aroused a lively interest. To most participants this theme - engineering control of air pollution sources - was the heart of the matter, and many general and specific questions were posed. The discussion centred around the following five major topics: development and production of air-cleaning installations; organization of technical control of air-cleaning installations; removal of dust from effluent gases; removal of specific toxic substances from industrial gases and unpleasant odour control; and control of air pollution from motor vehicles.
It was explained that the technical inspectorate of the All-Union Association for Gas Cleaning and Dust Removal carries out its work according to a pre-determined plan, in co-operation with the sanitary-epidemiological service and other interested agencies. Only qualified engineers are employed as technical inspectors. Some participants were interested in knowing whether any standards existed in the USSR for manufacturing air cleaning equipment. It was pointed out that Soviet practice showed research and development of air cleaning methods and standardization of equipment to be futile unless there were specialized factories for producing such devices. The question of emission standards was again raised and it was explained by Mr. Uzov that emission standards do not exist in the USSR and are not considered to be very useful in practice.

Dust removal from industrial flue gases was discussed both in plenary session and during the visit to the Semibratovo branch of the NIIOGAZ. The participants showed much interest in the design and performance of "needle" discharge electrodes. Investigations carried out in the NIIOGAZ laboratories have shown that the drift speed of particles and consequently the intensity of gas removal can be greatly increased by using such electrodes. Other topics discussed included reverse corona discharge which appears when the specific resistance of dust particles exceeds $10^9$ ohms per centimetre; the design and efficiency of centrifugal dust separators in conjunction with cyclones; cyclone efficiency testing; multi-cyclone installations; direct-flow cyclones; and high temperature gas filtration installations.

Much interest was also shown in different problems of sulfur dioxide removal from effluent gases. Technological methods exist but all of them become uneconomic if the concentration of sulfur dioxide in the gas falls below 0.15 per cent. However, if the concentration is above 0.17 per cent. most methods become applicable. The problem is what to do when the concentration is of the order of 0.10 per cent. to 0.15 per cent. It was explained that in such cases only the magnesite, the ammonia-autoclave and the ozone catalytic processes can be used. (Gaseous effluents with an $SO_2$ content below 0.15 per cent. are frequent in many industrial plants in India.) A general recommendation on procedures for treating these gases cannot be given, and each case has to be considered separately as many factors will determine the method of choice. The total volume of gases is an important factor. The production of sulfuric acid from $SO_2$ becomes economically sound when the $SO_2$ concentration is above 2 per cent. but this also depends on the demand for sulfuric acid.

Many speakers were eager to obtain more information about the removal of specific toxic substances emitted in the gaseous wastes of chemical plants. Air flotation followed by catalytic combustion is used for removing organo-phosphorus compounds from gaseous effluents; the method works, but is expensive. On the other hand, chlorinated hydrocarbon pesticides are removed together with other inactive dusts; this applies to the removal of arsenic (As$_2$O$_3$) as well. There were also questions about methods for controlling unpleasant odours, a common problem in many countries. (In Mexico, craft pulp production processes presented a problem but a technological method has now been found to reduce odour intensity. There are 43 fish-meal plants operating in Peru and as yet there is no simple method to control the odours.) Some industries try to 'mask' them, but this is not the practice in the USSR. When asked about methods used to control unpleasant odours from craft pulp operations, Professor Friberg said that there are from 40 to 50 craft pulp mills in Sweden, and they smell, particularly the older ones. At the moment nothing is being done about these older plants because it would be too expensive. Three or four new factories were recently built; all of them use some control method (emission of waste gases through high stacks, etc.); black liquor oxidation followed by chlorine scrubbers is also used, but this is an expensive process.

Some technological problems relating to air pollution control in the iron and steel industry and non-ferrous metallurgical plants were also analysed. The current practice in the USSR for cleaning effluents from steel converters is to use after-burners and turbulent Venturi-scrubbers, and foam units for cooling the gases. A new process is being studied now which does not involve after-burning; after passing through a battery of scrubbers, the gas will be used for heating, steel production, or ammonia synthesis.
The control of air pollution from automobile exhaust gases in the USSR was another major subject of the discussion. The Soviet Government decided eight years ago to forbid the use of tetraethyl lead in all large cities. The decision was based mainly on the MPC for lead in the ambient air, as adopted by the USSR Ministry of Health. Measurements carried out in some cities showed a considerable decrease of the lead content in the ambient air since this measure was enforced. Starting from 1968, automobiles will have to use catalytic combustion devices or 'neutralizers'. The efficiency of 'neutralizers' in reducing the content of carbon monoxide, oxides of nitrogen and hydrocarbons is, on average, from 70 to 80 per cent. Experience accumulated by Professor Varšavskij's laboratory after four years of road testing shows that 'neutralizers' may be used over 30,000 kilometres without reduction in efficiency. The cost of 'neutralizers' is about 1 per cent. of the cost of a car. Soviet research and development in the field of re-design of internal combustion engines was also discussed.

OTHER SUBJECTS DISCUSSED

Discussions both in plenary sessions and during informal afternoon meetings covered a wide range of topics some of which were not mentioned earlier in this report.

An important discussion which should be briefly reported here concerned the present status of air pollution problems in the participating countries. Air pollution problems and the approach to their solution vary widely from country to country, depending on geographical situation, climate, state of industrial development, population density, the social and economic structure and local habits. Some of the participating countries such as Japan and India have an air pollution monitoring control programme which is well under way. Most of the Latin American countries are just starting air pollution control activities but in some of them, air pollution monitoring and control programmes are developing rapidly. The European countries participating in the Seminar (Bulgaria, Hungary, Poland, Romania and Yugoslavia) have many features in common and their air pollution programmes are similar. On the other hand Middle Eastern countries (Turkey, Iran and UAR) and Pakistan are difficult to compare owing to large differences in climate, local habits and stage of industrial development. All of them are in the initial phase of air pollution control since other public health problems still take precedence.

All the participants felt that the exchange of information on air pollution control programmes had been of great benefit, and that this item should be included in the programme of any future Seminar.

The participants also discussed the training of sanitary physicians and sanitary engineers in the USSR. Sanitary physicians in the USSR are trained in the faculties of hygiene and sanitation of the medical institutes (medical schools). Secondary education is a prerequisite for admission to a medical school (i.e. 10 grades of a general education school or eight grades of a general school plus two years at a medical 'technicum'). The sanitary physician's training lasts six years and successful students become qualified sanitary physicians. Preliminary specialization in epidemiology, communal hygiene, occupational hygiene, etc., takes place in the sixth year. After three years of independent work, sanitary physicians follow a three- or four-month course of specialization at the Institute of Advanced Medical Studies. A further three-months' training is given every five years at the same Institute. Apart from that, courses of shorter duration (one month) are also offered in special subjects. There are also correspondence courses, of seven to nine months' duration, the last month being spent at the Institute.

Sanitary engineers in the USSR are trained at various faculties of technical institutes. One of the main institutes in this field is the Kujbyšev Civil Engineering Institute in Moscow where there are faculties of water supply, sewerage, ventilation, and so on. A diploma of engineering is awarded on completion of such training. Post-graduate training of sanitary engineers is provided in specialized research institutes; for instance, the Academy of Communal Economy or 'NIIOGAZ'.

Potential research workers in all branches of pure or applied science as well as in medicine and engineering, are trained through post-graduate studies called 'aspirantura'. Candidates are selected by competitive examination. In order to sit for the entrance examination candidates must have a university diploma or equivalent qualification, they should not have passed their thirty-fifth birthday and they must have shown aptitude for research work. The duration of this advanced training is three years and during this period the student receives a state scholarship.

CONCLUDING DISCUSSION

The concluding discussion of the Seminar brought out many subjects of common interest to all the participants. Some topics had already been dealt with, but some new subjects were also introduced. Some participants pointed out that exchange and dissemination of information on air pollution should be intensified. Others felt that a manual of recommended control methods was needed and that it would be very useful to have recommendations on what should constitute a minimum air pollution control programme for developing countries (covering personnel, laboratory space, and equipment needed for such a programme). The establishment of an international reference centre with a corresponding network of regional and national collaborating laboratories was also considered necessary. The usefulness of future seminars of this kind would be enhanced if still more time were devoted to practical field work (visits and demonstrations of equipment and methods of work). It was also felt that more regional or international training courses in air pollution control were needed.

It was unanimously agreed that:

(a) the USSR was a particularly happy choice of location for this Seminar for it had offered participants the opportunity to gain first-hand knowledge of Soviet achievements in this field;

(b) it would be of great benefit to the participants in the Seminar, as well as other workers in the field, if the full texts of the lectures presented were compiled and widely distributed;

(c) it is necessary to have some internationally recommended criteria and guides to air quality; these should be realistic and attainable by the technological methods and financial means available, even in the developing countries; such criteria and guides should be subject to periodic revision and change in the light of new scientific evidence;

(d) strict international standardization of analytical methods for the determination of air pollutants is neither feasible nor desirable; it is preferable to have a set of recommended methods so that a suitable choice can be made by each laboratory depending on the facilities available;

(e) a system for laboratory inter-comparison of analytical methods and for the exchange of analytical standards would be valuable;

(f) detailed recommendations on how to carry out an air pollution survey and how to collect systematic air pollution data are needed urgently;

(g) the reporting of data and the basic statistical methods used in the analysis of data should be uniform.
General and Organizational Problems
WHO activity in the field of air pollution control started in 1955 when the WHO Regional Committee for Europe recognized air pollution as a serious problem and concluded that a combined effort by the countries of Europe was required for its solution. The recommendations of this Committee led to the Conference on Public Health Aspects of Air Pollution, convened by WHO in Milan, 6-14 November 1957. Twenty-one European countries participated in this, the 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 Co-operation. 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 giving 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 worsening. 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 to press for immediate control measures.

The Conference reached the following conclusions, which have since been expressed in one form or another by practically every national or international conference on air pollution:

"Air pollution constitutes an increasing but avoidable hazard to the health and well-being of the community. Much information is urgently needed on its precise effects on man, animals and plants, and on the most satisfactory means of control. Nevertheless, sufficient is already known to justify immediate action, including the education of public opinion, the setting up of national advisory bodies, the training of suitable personnel for research and control, routine measurements of pollution, and a wider use in industry of the control devices at present available, backed, if necessary, by suitable legislation. There is a pressing need for standardization of measuring apparatus and techniques, and an international glossary of terms used in work on air pollution would be valuable. The Conference recommended that WHO should arrange for the collection, translation, condensation and dissemination of information on air pollution including, as a first stage, the compilation of a list of various organizations and associations concerned with all problems of air pollution."

Immediately following the Milan Conference, the first meeting of an Expert Committee devoted to air pollution was convened in Geneva, 18-23 November 1957. Thus, states the report of this meeting, "the World Health Organization recognizing its responsibility in the matter of air pollution 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".

The Expert Committee discussed the nature and causes of the problem, methods for measuring pollutants in 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, effects upon human health, effects upon animals, effects upon vegetation, and economic and sociological effects. However, it was the primary concern of the Committee to take cognizance of the WHO definition of 'health' which, in the words of the Constitution, "is a state of
complete physical, mental and social well-being and not merely the absence of disease or infirmity. Concerning effects upon human health, the Committee report states:

"With regard to those air pollutants that are known and those that are suspected to be causes of harm to health, it is the opinion of the Committee that the current status of knowledge is not adequate to establish standards of what levels of concentration are safe for humans.

It is apparent from the foregoing that much more medical and epidemiological research is needed if control of air pollution is to be more soundly based on the need to safeguard human health. It is recommended that such research, carried out by competent personnel in many selected places in the world, should be directed in the following avenues:

(a) Field epidemiological investigations of those diseases currently suspected of being causally related to air pollution. Such diseases should include chronic bronchitis (in the broadest definition of that term) and primary lung cancer. To assist in such investigations, there should be agreement among nations on the definitions of the clinical conditions to be studied and for which the morbidity and mortality rates are to be compared by the epidemiologists.

(b) Suitably controlled laboratory investigations of substances that are suspect as air pollutants. Such investigations should include exposure of various species of animals, and must include the inhalational route of administration at levels of concentration that are known to be reached in the ambient community air. When gases are used in such toxicological investigations, experimental protocols should include exposure to the gases together with some inert aerosols. When toxicological investigations include exposure of human volunteers, due care must be exercised to avoid irreversible injury to the volunteers."

The Expert Committee made many specific recommendations relative to standardization, research, collection and dissemination of information, administration and legislation, training, education of the public, and 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 14 chapters and contributed by experts from seven countries.

In considering the administrative aspects of air pollution control the Committee also discussed the matter of emission standards, but did not address itself to the subject of air quality criteria except to state, as already quoted, that "the current status of knowledge is not adequate to establish standards of what levels of concentration are safe for humans".

In 1950, the Regional Office for Europe began a detailed study of the problem in collaboration with organizations in all European countries interested in air pollution research and control. It became clear that there was a widespread, but rather uncoordinated, interest in the epidemiology of air pollution and it was decided to arrange an international meeting for a discussion as to the lines along which epidemiological and related research might usefully develop. The symposium that was the outcome of this decision was held in Copenhagen, 13-16 December 1960, and was attended by participants from 14 European countries.

The meeting discussed the main questions confronting epidemiologists and others concerned with the effects of air pollution on health, i.e. how to assess the nature and extent of contamination of populated areas by various noxious components of the air, how to discover whether or not the prevailing levels of pollution are harmful to health, and how to fix limits of maximum allowable concentrations.
In discussing standardization of methods, it was pointed out that the need for using methods of measurement which will give comparable results had long been recognized. The standardization of measurements for research purposes was, of course, not envisaged, nor was it feasible or desirable to restrict the use of methods which have proved useful for dealing with local problems and which have provided in some instances a continuous record of empirical measurements extending over several decades. However, much could be done by standardization to bring current techniques to a common basis. The variants of some of the best methods are capable of unification. In some instances a number of different methods which give satisfactory results could be closely specified and approved. In other instances as, for example, with certain types of dustfall gauge, although the results differ, they may be equated approximately by means of certain experimentally determined factors.

It was also suggested that there was a need for a more uniform usage of air pollution terminology. Probably most confusion arises over the word 'dust' which is applied in some publications to 'smoke', in some to 'dustfall', and in some it is not clear which is intended; hence the preparation of an international glossary would be a very worthwhile undertaking.

In considering the value of epidemiological investigations of morbidity for studies of air pollution effects, it was agreed that the use of morbidity statistics rather than mortality figures was advisable for a number of reasons. The use of morbidity figures must, of course, be accompanied by a clear indication of how they are collected - from hospital in-patients, out-patients, family doctor consultations, absence from work, or questionnaires from the general population - and it must always be remembered that they apply only to these circumstances and must be interpreted with this in mind.

Such studies could be facilitated by setting up centres for research into air pollution and related morbidity. International co-operation and the use of generally accepted criteria and methods would make the results of such studies more valuable. However, there should be no illusions about securing internationally comparable morbidity data; it is a difficult matter.

The report of this symposium (Epidemiology of Air Pollution, WHO Public Health Papers No. 15) concludes that epidemiological studies provide one of the best means at present available for studying the influence of air pollution on health. In the planning and execution of such studies it is important that medical and chemical experts should co-operate in order to ensure that observations of pathological effects are matched by the fullest possible information on the air pollutants most closely related to those effects. Convincing evidence of the effects of specific air pollutants may be obtainable from internationally co-ordinated investigations carried out under varying climatic and environmental conditions.

Variety in instrumentation and methods is important. Continuous recorders and sequential samplers are useful in studying peak concentrations but, for most epidemiological investigations, simpler apparatus providing average results spread over somewhat longer periods, such as 24 hours, are likely to be more generally useful. It reiterates the need for standardizing instruments, units of measurement, sampling and analytical methods, and terminology, for generally accepted methods suitable for the specific needs of epidemiological research are required. The standardization of medical terminology is an essential prerequisite for much of the epidemiological research on air pollution, since diagnostic criteria used by doctors may differ. At present there are important variations between countries which invalidate most international comparisons.

Much of the success of epidemiological studies depends on the quality of medical studies available. Mortality statistics, although collected in every country, vary in quality and provide information significant for air pollution research only in respect of the larger conurbations. Morbidity indices should be more sensitive to the effects of air pollution, but no really satisfactory figures were found to exist in any of the countries represented at the symposium. Greater attention should therefore be given to the study of morbidity with a view to establishing indices that will prove more suitable for use in international comparative studies. In the absence of comprehensive morbidity indices,
sources such as data obtained from insurance schemes or hospital admission records, and from special population groups such as school children or the patients of hospital clinics for chest diseases are capable of providing useful information on a local or regional basis.

The WHO Regional Office for Europe devoted its Eighth European Seminar for Sanitary Engineers entirely to the subject of air pollution. This Seminar, which took place in 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 19 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 surveys and pollutant measurement procedures, and legislative and administrative measures for control.

One point made at this meeting was that there was, as yet, no general agreement on fundamental principles on which to base maximum permissible levels, and WHO took up this important question at a symposium at which the rationale for air quality criteria, in particular, was discussed. In reviewing the situation as regards air quality, it became apparent that although several governments had adopted 'standards', they varied widely because they had been based on different criteria.

On the matter of international collaboration, the symposium acknowledged that there was great interest in many countries in common air pollution problems, and progress in this field could be accelerated by international collaboration and exchange of information. Such co-operation is particularly necessary in view of increasing evidence that air pollution is not merely local in character but can be widely dispersed over extensive areas transcending local and national boundaries.

Work carried out so far to facilitate international comparison of results of experiments and studies appears to be hampered by lack of uniformity in nomenclature and units of measurement, so that international agreement on these questions undoubtedly has a high priority.

Many of the methods used in the sampling and analysis of air pollutants are non-specific owing to the complexity of the chemical and physical properties of polluted air. Empirical methods have therefore been adopted in the various countries in order to proceed with aero­metric surveys and the study of air pollution effects. Although these empirical methods may have served their purpose well within the various countries, any attempt to reach international agreement on levels at which effects occur must be based on predetermined and comparable procedures. In the course of these last years, WHO, in collaboration with a number of experts, has prepared a document entitled Guide to the selection of methods for measuring air pollutants in which are described the main purposes for which air pollution measurements are made. This same document recommends units for expressing the results of air sampling and analysis. It also discusses some of the fundamental principles on which these measurements are based, and describes several methods now in use in various countries for the identification and estimation of the most common air pollutants.

Research into air pollution and control measures is being promoted by WHO by the exchange of scientific information, by the provision of fellowships for long-term studies and short-term instruction, by organizing courses for technical personnel, and by stimulating and assisting specific research. A guide on air quality criteria for assisting countries to develop national standards is also being considered and preliminary work is being carried out towards that end.

Many other disciplines, for example, meteorology, have an important bearing on air pollution; therefore, WHO is collaborating with other agencies concerned, particularly with the Commission on Aerology of the World Meteorological Organization.
In the broad WHO programme aimed at the exchange and diffusion of information, air pollution legislation has received special attention. The International Digest of Health Legislation, published quarterly by WHO in two separate editions, English and French, contains a selection of health laws and regulations, among others those relating to air pollution control. Recently A survey of existing legislation - on air pollution - covering the legislation of 13 countries, was published separately.

WHO has attempted to clarify the relative health hazards of exhausts from motor vehicles. It recently issued the results of a study on the Public Health Aspects of Emissions from Diesel Vehicles and will organize in 1968 an Expert Committee to consider health hazards which might be associated with the urban air pollution caused by ever-increasing motor vehicle traffic.

A detailed review of all WHO activities in the field of air pollution control would obviously be out of place at this meeting and participants are referred to the main publications of WHO, on display in the room, for the results of some of these activities.

In conclusion, the work of WHO is summarized briefly as follows:

Studies to elaborate and verify methods for measuring a number of common air pollutants, and to ensure accuracy of data and comparability of results.

The development of suitable methods for air quality and epidemiological surveys in countries with differing air pollution problems, in order to identify these problems, assess their severity, and advance our knowledge of the effects produced on man and the environment. Studies on guides to acceptable air quality levels through international collaboration, to enable countries affected by air pollution to set clear objectives for any control or preventive measures they may wish to take.

Support for studies on control devices, or alternative measures, for those pollutants for which adequate control is not yet in sight, such as petrol fumes, and for processes producing pollutants such as sulfur dioxide, carbon monoxide, lead, oxides of nitrogen and possibly others.

Support for research in all phases of the programme. Some research is already under way but much will have to be commissioned, supported and co-ordinated. Also systematic collection and dissemination of data will have to be initiated on the results of air pollution investigations, on measurements and effects of air pollutants, and on the efficiency of control methods and of other action taken to abate air pollution.

Training of personnel at all levels. Training in the prevention and control of air pollution is already being provided in some institutions, but increased support is essential both for existing institutions and for the creation of new ones, wherever needed.
REFERENCES

1. World Health Organization (1958) Expert Committee on Environmental Sanitation

2. Barker, K. et al. (1961) Air Pollution, World Health Organization: Monograph Series,
   No. 46, Geneva

   No. 15


5. World Health Organization (1963) Int. Dig. Hlth Legis., 14, 187

6. The Diesel Engine and Atmospheric Pollution (1967) WHO Chronicle, 21, 201
THE ORGANIZATION AND STRUCTURE OF THE SANITARY-EPIEMIOLOGICAL SERVICE IN THE USSR

by

P. P. Ljarskij

The new regulations on the state sanitary surveillance were approved by a decree of 29 October 1963 of the Council of Ministers of the USSR. According to these regulations the state sanitary surveillance is carried out by the sanitary-epidemiological service of the Ministry of Health of the USSR and the sanitary-epidemiological services of the constituent republics.

Medical services of other ministries, exercising sanitary supervision of departmental establishments, are under control of the sanitary-epidemiological service of the Ministry of Health.

The regulations of October 1963 specify the structure of the sanitary-epidemiological service and define the responsibilities and legal status of health officials in charge of the state sanitary surveillance. The duties and rights of the sanitary-epidemiological service with respect to the improvement of sanitary conditions in the country and prevention of disease have also been established by the same regulations.

The sanitary-epidemiological services in the USSR are responsible for the organization and implementation of nation-wide programmes aiming at elimination and prevention of environmental pollution (air, water, soil); improvement of living and working conditions and prevention of general, occupational and infectious illness. The state sanitary surveillance is also concerned with the implementation of health standards and sanitary-epidemiological and sanitary-hygienic rules in design, construction and exploitation of residential quarters, industrial establishments and various community facilities (education and recreational establishments, restaurants, etc.). The sanitary-epidemiological service is an organic part of state health services and has a centralized, functional administration. The structure of the sanitary-epidemiological services in the USSR is shown in Fig. 1.

The sanitary-epidemiological service which also performs the functions of the former State Sanitary Inspectorate is controlled by the following functionaries, as appropriate:

The Chief Sanitary Physician of the USSR (the Chief Medical Officer of Health) who is also a Deputy Minister of Health of the USSR;

The chief sanitary physicians of the constituent republics who are at the same time deputy ministers of health of the constituent republics;

The chief sanitary physicians of autonomous republics, krajs, oblasts, okrugs, towns, town 'raions' - they are deputy ministers of health of the autonomous republics and deputy heads of the corresponding departments of health, respectively.

The chief sanitary physicians of rural 'raions' - deputy chief physicians of the rural rajons;

The chief sanitary physicians of water transport basins, ports and water transport sections.

The terminology in this and other papers on the organization of public health services in the USSR follows closely the terminology used in the article on central and local public health administration in the USSR, published in International Digest of Health Legislation (1965) 15, 197.
Fig. 1 - The Structure of the Sanitary-Epidemiological Service in the USSR
The chief sanitary physicians of the corresponding administrative territories are also in charge of the territorial sanitary-epidemiological establishments and units (sanitary-epidemiological stations and sanitary-epidemiological departments), and are at the same time deputy chiefs of the (administrative) health departments of these territories. This system gives to the heads of the sanitary-epidemiological services the appropriate legal status within the general system of the state health services and ensures their day-to-day participation in the organization and management of complex health programmes carried out by all the establishments of the health service.

The administrative authorities and establishments of the sanitary-epidemiological services, responsible for the state sanitary surveillance, are:

- The Chief Sanitary-Epidemiological Directorate of the Ministry of Health of the USSR;
- The chief sanitary-epidemiological directorates of the ministries of health of the constituent republics;
- The sanitary-epidemiological stations ('sanepid' stations) of the constituent and autonomous republics, krais, oblasts, okrugs, towns and town rajons, water basins, ports and water transport sections;
- The sanitary-epidemiological departments of 'rajon' hospitals in rural rajons.

The Chief Sanitary-Epidemiological Directorate of the Ministry of Health of the USSR is responsible for the organizational and methodological guidance of the sanitary-epidemiological services in the country; it supervises their activities and gives suggestions as to the improvement of organizational forms and methods of work; it also takes care of the material and technical basis of their work.

The principal tasks of the Chief Sanitary-Epidemiological Directorate of the Ministry of Health of the USSR in the field of state sanitary surveillance, are: to study sanitary conditions in the country and, on the basis of such studies, to prepare and propose drafts of laws and government regulations aiming at improvement of sanitary conditions and prevention of general, occupational and infectious illness; to propose health standards; to control the execution of various sanitation projects; to supervise the execution of programmes for health education of the public; to improve sanitary-epidemiological services in the country in close collaboration with members of the public, trade unions, organizations of the Red Cross and the Red Crescent, citizens' councils attached to sanitary-epidemiological and other medical establishments and scientific-medical and technical societies; to see that the requirements of health standards are incorporated into the all-union design and construction standards and to take corresponding decisions; to carry out quality control of bacterial, rickettsial and viral preparations and vaccines and sera prepared for public health purposes.

The responsibilities of the sanitary-epidemiological directorates of the ministries of health of the constituent republics are similar to the responsibilities of the Chief Sanitary-Epidemiological Directorate of the USSR, but are restricted to the territory of the constituent republic. For example, they organize the state sanitary surveillance in the republic, prepare republican laws and regulations for the protection of health, supervise the implementation of sanitary regulations and health standards in the territory of the republic, etc. A specific responsibility of the sanitary-epidemiological directorates of the ministries of health of the constituent republics is to direct and supervise the work of the republican sanitary-epidemiological stations.
The republican sanitary-epidemiological station is the authority responsible for organizational and methodological guidance and practical assistance to other sanitary-epidemiological establishments in the territory of the republic: sanitary-epidemiological stations of oblasts, towns and rajons; sanitary-epidemiological departments of rajon hospitals of rural rajons and other health establishments of the republic. At present there are about 4,500 sanitary-epidemiological stations in the USSR, 3,000 being in the rural districts and 1,400 in towns. This number includes about 150 'sanepid' stations of autonomous republics, oblasts and krajs, and about 20 sanepid stations of the water transport system.

Sanitary-epidemiological stations are autonomous, specialized establishments of the sanitary-epidemiological service with their own budgets. The budgets of the sanitary-epidemiological stations consist of funds allocated by the health departments. These funds include regular allocations for routine sanitary and epidemiological work as well as special funds obtained from industry and various other organizations for special sanitation and preventive medical projects.

With respect to the state sanitary surveillance, the chief sanitary physician of the 'sanepid' station has the authority of the chief sanitary physician of the territory or of the water transport basin. He is appointed by the council of ministers of the constituent or autonomous republic, and by the executive committees of the soviets of workers' deputies of the krajs, okrugs, towns, rajons, respectively, in agreement with the superior health authorities. The chief sanitary physician of the sanitary-epidemiological station disposes with the budget of the station and also has the right to employ and dismiss the personnel of the sanepid station. The tasks and responsibilities of sanitary-epidemiological stations are defined by special regulations. Special tasks of sanitary-epidemiological stations of water basins, ports and water transport sections comprise preventive and routine sanitary surveillance of water transport facilities as well as sanepid services of fishing ports and vessels of the fishing fleet. The organization and staffing of sanepid stations are determined by the standards of the sanitary-epidemiological service and depend on local requirements. The staff of sanepid stations consists of physicians of various sanitary-epidemiological profiles (epidemiologists, parasitologists, epidemiologists-disinfectionists, epidemiologists-rabies specialists; sanitary physicians specialized in different branches of hygiene - occupational health, community hygiene, food hygiene, radiation hygiene, child and adolescent health) as well as other specialists with higher education (entomologists, biologists, chemists, engineers); and various medical workers with secondary medical education (assistants to epidemiologists, assistants to sanitary physicians, laboratory technicians with secondary educations).

In view of the responsible and complex tasks of the sanitary-epidemiological service, special attention is paid to the qualifications and further training of the staff. Specialization and advanced training of physicians is carried out in the institutes for advanced medical studies and in the faculties for advanced training of medical institutes and universities, as well as through training and specialization courses organized by establishments for higher medical education, research institutions and large sanitary-epidemiological stations. All physicians in the sanitary-epidemiological service are subject to certification. The same applies to assistants to sanitary physicians of all specialities and to laboratory technicians in bacteriology and virology. The certifying commissions are attached to the ministries of health of the constituent and autonomous republics and to the institutes of advanced medical training, as well as to some special training establishments. The certifying commissions consist of chief specialists, specialists of integrated disciplines, representatives of medical and scientific societies and trade unions of medical workers. The special allowances of sanitary-epidemiological personnel depend on the qualification category and grading awarded by the certifying commission.

Sanitary-epidemiological stations have their own transport facilities, laboratories and the necessary equipment, in accordance with a list approved by the Ministry of Health of the USSR.
THE ROLE AND ACTIVITY OF THE USSR SANITARY-EPIDEMIOLOGICAL SERVICE IN AIR POLLUTION PREVENTION

by

M. K. Nedogibčenko

An organized nation-wide air pollution control programme was initiated in the USSR in May 1949 when a decree on air pollution abatement and improvement of sanitary-hygienic conditions of inhabited areas was issued by the Government. In 1963 another Government decree was published on prevention of air pollution by industrial effluents and automobile exhausts. Further evidence of the growing interest in environmental pollution is the law on protection of nature, which has been adopted by the majority of the constituent republics.

These laws bind the ministries, other government authorities and industrial organizations to design and construct factories, industrial plants and units in such a way, and to apply such technological processes, as to ensure maximum utilization of raw materials and fuel and prevent the discharge of noxious substances into the atmosphere. If it is impossible to eliminate the emission of noxious substances into the atmosphere, the law requires that efficient cleaning and recuperating units be constructed so that the concentrations of noxious substances in the environment do not exceed the maximum permissible levels. Thus, the law on the protection of nature provides a solid legal foundation for the sanitary protection of ambient air. An all-union law on the protection of nature is now being prepared.

In general, the sanitary protection of ambient air is ensured in the USSR by the following system of compulsory measures:

a No power station, industrial establishment, workshop or unit can be commissioned or put into operation, either permanently or temporarily, unless measures have been taken to control the emission of noxious substances into the atmosphere in such a way as to reduce their concentration in the ambient air below the established limits. An authorization of the sanitary-epidemiological services is needed before any plant or installation, which is a potential source of air pollution, is put into operation.

b Plans for construction or expansion of industrial establishments cannot be approved unless the provision has been made to install efficient effluent purification equipment. New regulations on the state sanitary surveillance require that all plans for construction of industrial establishments and installations be approved by the sanitary-epidemiological service.

c New factories which are not equipped with modern effluent cleaning installations (because adequate technological solutions of the problem do not exist) can only be located outside inhabited areas, parks and forest belts. The location must be approved by the sanitary-epidemiological authorities. Depending on the type of industry and the capacity of the plant, the location is permitted at a distance of six to 15 km from the inhabited area.

d All other industrial establishments must be separated from residential areas by a sanitary protective zone. The State Building Construction Committee has classified all industrial establishments into five groups, depending on the type of effluents, the conditions of the technological process and methods used to control the discharge into the atmosphere. The widths of the sanitary protective zones are as follows:

<table>
<thead>
<tr>
<th>Class</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>1000 m</td>
</tr>
<tr>
<td>Class II</td>
<td>500 m</td>
</tr>
<tr>
<td>Class III</td>
<td>300 m</td>
</tr>
<tr>
<td>Class IV</td>
<td>100 m</td>
</tr>
<tr>
<td>Class V</td>
<td>50 m</td>
</tr>
</tbody>
</table>
The sanitary-protective zone may be increased up to three times if the sanitary-epidemiological authorities find it necessary (large capacity of the plant, ineffective effluent purification, local meteorological conditions, etc.,)\textsuperscript{a} The width of the sanitary-protective zone for large industrial establishments or groups of plants discharging such quantities of effluents that the resulting air pollution could have very unfavourable effects on the health of the population or on the vegetation, has to be established by the sanitary-epidemiological service in each particular case.

The zoning regulations are based on extensive hygienic investigations which contributed to our understanding of laws governing the distribution of particular matter and gases in air around pollution sources.

The hygienic assessment of the ambient air of inhabited areas is based in the USSR on the maximum permissible concentrations of noxious substances, established by the Ministry of Health of the USSR. The present list of the maximum permissible concentrations contains 96 substances.\textsuperscript{b}

(e) Yearly national economy plans make special provision for construction of effluent control installations in industrial establishments which are already in operation.

(f) There is a special inter-ministerial organization for technical surveillance of effluent cleaning installations, the Technical Inspectorate of the All-Union Association for Gas Cleaning and Dust Control. In 1966 alone, the Technical Inspectorate examined about 13,000 gas cleaning devices.

(g) There is also a continuous state sanitary surveillance of the ambient air. According to the regulations approved by the Council of Ministers of the USSR in 1963, the sanitary surveillance of air is the responsibility of the sanitary-epidemiological services. The basic unit of the sanitary-epidemiological service directly involved in this work is the sanitary-epidemiological station. Sanitary-epidemiological stations have special sections and laboratories for investigation of the ambient air, which are operated by specialized staff (sanitary physicians, chemists, engineers and laboratory technicians).

The main tasks of the sanitary-epidemiological station in the field of sanitary protection of the ambient air are: to register all industrial establishments, plants and units (in operation, under construction or in the planning stage) the operation of which involves the pollution of air of inhabited areas; to investigate and make hygienic assessment of the quality of ambient air in towns and industrial centres; to study effects on health of air contaminated by industrial effluents and automobile exhausts (standardized methodology established by the Sanitary-Epidemiological Directorate of the Ministry of Health of the USSR is used in such investigation); to elaborate sanitary requirements for industrial effluent control for inclusion in the national economy plans and complex sanitation programmes; to supervise the implementation of such plans; to carry out strict preventive sanitary surveillance, which begins with the siting of an industrial establishment and ends with its commissioning, and to issue decisions with regard to the plans of construction, reconstruction and expansion of industrial enterprises; such decisions are binding.

\textsuperscript{a} This classification applies to individual plants.

\textsuperscript{b} See Annex - USSR Air Quality Standards.
If for some reason it is impossible to implement efficient effluent control measures, and the discharges from the industrial establishment affect unfavourably the living conditions in the area, the sanitary-epidemiological service may require that the whole factory, or part of it, be transferred to another locality. Of great significance for ambient air sanitation in the USSR are the gasification, electrification and introduction of district heating systems which are carried out on a large scale.
The Sanitary-Epidemiological Station (the 'Sanepid' Station) of the City of Moscow was organized in 1950 by merging the separate city sanitary service and the city epidemiological service. The Sanitary-Epidemiological Station is the central establishment of the city sanitary-epidemiological service; it organizes and controls all the preventive measures for reducing the general, occupational and communicable disease morbidity in the City of Moscow. Both from the organizational and methodological point of view, the city Sanitary-Epidemiological Station directs and supervises 17 'rajon' sanitary-epidemiological stations, the sanitary-epidemiological station at the Exhibition of Soviet Economic Achievements, the sanepid station of the city underground railway ('Metropolitan'), the sanepid station of the town Zelenograd, the city disinfection station, the city epidemiological post for the transport of infectious patients (attached to the First Aid Station), and the city Health Education Centre.

The principal responsibility of the City Sanepid Station is to study and analyse the sanitary-epidemiological conditions in the City of Moscow and the morbidity of its population. Such studies are the basis for setting up a comprehensive plan for sanitation and control of epidemics, for preparation of sanitary regulation, for decisions of the Moscow Soviet of Workers' Deputies, for orders of the City Health Department, for the decisions of the Chief Sanitary Physician of the City of Moscow and other similar documents.

A comprehensive programme for the health education of the public and for the sanitation of living and working conditions is carried out through the rajon sanepid stations, in close collaboration with the Red Cross Society and the public.

The City Sanepid Station follows the methodological instructions of the Sanitary-Epidemiological Directorates of the Ministry of Health of the RSFSR and the USSR. The Sanepid Station also maintains close relations with the local soviets, with Party organizations, with various community services, and with professional societies of hygienists and epidemiologists.

The director of the Sanepid Station has the title of the Chief Physician. He is also the Chief Sanitary Physician of the City of Moscow and Deputy Head of the City Health Department. The Chief Physician is assisted in his work by a sanitary-epidemiological council, a sanitary-technical expert council, a council of citizens, a council of 'fel'dżers', a laboratory council and a scientific and methodological committee.

The Moscow City Sanitary-Epidemiological Station is located in a specially constructed five-storey building and has various well-equipped modern laboratories.

In collaboration with Moscow institutes of hygiene and chairs of hygiene of medical institutes, the Sanepid Station organizes various training courses. In the first semester of 1966 there were 169 on-the-job trainees and 7341 attendants of different seminars. The Sanepid Station also serves as a practical training unit for students of the sanitary-hygienic faculty of the Moscow Medical Institute, of the First Moscow Medical Training Centre and the Medical Training Centre of the USSR Academy of Medical Sciences (for medical technicians). The two-year post-graduate practical training of sanitary physicians ('ordinatura') is also carried out at the Sanepid Station. The specialists of the Moscow City Sanitary-Epidemiological Station are lecturers at the Central Institute for Advanced Medical Training. In the period 1963-1966 the Sanepid Station organized 16 conferences devoted to scientific and practical subjects. In 1966 there were 97 scientific and field study projects in progress.
Every three to four months the Sanitary-Epidemiological Station publishes an information bulletin describing its work. The results of routine work and field studies are also published.

The organizational structure of the Moscow City Sanitary-Epidemiological Station is shown in Table 1.

Within the Department of General and Municipal Hygiene and Sanitation there is a Section of Sanitary Protection of Ambient Air which is in charge of all air pollution control work of the station. The responsibilities of the sanitary-epidemiological stations in the field of air pollution control have already been discussed and need not be mentioned again. The rest of this paper will be devoted to a brief description of the air pollution surveillance network in the City of Moscow.

The 'diffuse' air pollution in the city of Moscow has been investigated since 1954. There are now 25 stationary air sampling stations distributed throughout the city. A certain number of these sampling stations are operated by the 'rajon' sanitary-epidemiological stations. At these points air samples are collected twice weekly on fixed days of the week and at fixed hours of the day. At sampling station points operated by the City Sanepid Station the air sampling is performed daily, in the morning and in the evening.

The 'zonal' air pollution in the vicinity of selected industrial establishments has also been investigated.

The air samples at the stationary sampling points are collected for the determination of sulfur dioxide, dust, soot, carbon monoxide and, to a smaller extent, for the determination of formaldehyde. In the vicinity of industrial sources air samples are usually collected for determination of specific air pollutants (organic solvents, lead, mercury, carcinogenic substances, etc.).

Various types of electro-aspirators are used for sampling; some of them can be switched on and off automatically at a predetermined time (automatic electro-aspirators LK-2, LK-2A, LK-3, LK-3A, LK-4). All types of aspirators can be used for both sampling of gases and suspended matter (dust). A useful device for air sampling in the vicinity of industrial establishments is the automobile aspirator which is connected to the intake tube of the carburettor when the engine is 'idling'.

The concentration of dust is determined by weighing the filters through which a certain volume of air has been aspirated. The filters used are synthetic fabrics Type FPA or FPP; the soot content is determined by measuring the optical density of paper filters; sulfur dioxide is estimated by a nephelometric method (aqueous solution of potassium chlorate is used as absorption liquid); a gas analyser titrimetric method is used for carbon monoxide; formaldehyde is measured by a colorimetric method using chromotropic acid.

In the course of 1957-58 the consumption of solid fuel was considerably reduced in Moscow. This was due to the implementation of a large-scale programme of district heating fuelled by natural gas, and to the replacement of coal by liquid fuel or natural gas in boiling plants and power stations. These changes immediately produced a significant reduction in air pollution level as illustrated in Tables 2 and 3.

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See summary of the lecture delivered by Dr M. K. Nedogibčenko.
TABLE I. THE STRUCTURE OF THE MOSCOW CITY SANITARY-EPIDEMILOGICAL STATION

A. Supervising Authorities

1. Ministry of Health of the USSR - Chief Sanitary-Epidemiological Directorate
2. Ministry of Health of the RSFSR - Chief Sanitary-Epidemiological Directorate
3. Moscow City Department of Health

B. Collaborating Institutions and Advisory Bodies

1. City Scientific and Professional Societies of Sanitary Physicians, Epidemiologists and Specialists for Communicable Diseases (2)
2. Chairs of Hygiene and Epidemiology (8)
3. Research Institutes in Hygiene and Epidemiology
5. Council of Sanitary 'Fel'd$ers' (Medical Assistants)
6. Council of the Public
7. Sanitary-Epidemiological Council on Co-ordination and Methodology
8. Sanitary Epidemiological Stations of other Government Departments (Ministries)

C. Internal Organization of the Moscow City 'Sanepid' Station

(a) Division of Sanitary Hygienic Activities

1. Department of General and Municipal Hygiene and Sanitation
   Sections
   - Sanitary Supervision of Planning
   - Sanitary Protection of Ambient Air
   - Hygiene and Sanitation of Housing
   - Hygiene and Sanitation of Public Buildings, and Therapeutic and Prophylactic Establishments
   - Water Supply and Sanitary Protection of Water and Soil
   Laboratories
   - Sanitary Chemistry
   - Physico-Chemical Methods

2. Department of Occupational Hygiene and Industrial Sanitation
   Sections
   - Physiology of Work and Occupational Pathology
   - Industrial Sanitation
   Laboratories
   - Industrial Sanitary Chemistry
   - Physical Methods of Analysis
   - Toxicology

3. Department of Nutrition Hygiene and Food Sanitation
   Sections
   Laboratories
   - Sanitary Chemistry
   - Toxic Residues in Food

4. Department of Childrens' and Adolescents' Health and of School Sanitation
   Sections
   Laboratories
   - Sanitation and Hygiene
   - Physico-Chemical Methods
(b) Division of Epidemiological Activities

1. Department of Epidemiology and Microbiology

   Sections
   - Epidemiology
   - Registration of Communicable Diseases
   - Rabies Control

2. Department of Communicable Diseases

   Sections
   - Epidemiology
   - Zoological Parasitology
   - Sanitary Quarantine
   - Vaccination

3. Department of Parasitology

   Sections
   - Epidemiology
   - Entomology
   - In-Patient Department

(c) General Departments

1. Department of General Laboratories

   Sections
   - Sanitary Bacteriology
   - Acoustics and Vibrations
   - Radiation Hygiene

2. Department of Organization and Methodology

   Sections
   - Organization and Methodology
   - Statistics
   - Medical Library

3. Department of Administration and Management

   Sections
   - Administration
   - Budget and Finance (Accounting)
   - Economy and Supplies

D. Sub-Ordinate Organizations

1. 'Rajon' Sanitary Epidemiological Stations (17)
2. Sanitary-Epidemiological Stations of: Zelenograd 'Metropolitan' Exhibition of Soviet Economic Achievements
3. City Disinfection Station and Inter-'Rajon' Disinfection Departments
4. City Health Education Centre and 'Rajon' Health Education Centres
5. City Post for Transport of Infectious Patients
Table 2. Dust concentration in the ambient air of Moscow
(in mg/m³)

<table>
<thead>
<tr>
<th>Area</th>
<th>1956</th>
<th>1958</th>
<th>1960</th>
<th>1962</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Industrial</td>
<td>0.98</td>
<td>1.0</td>
<td>0.36</td>
<td>0.46</td>
</tr>
<tr>
<td>Residential</td>
<td>0.74</td>
<td>0.67</td>
<td>0.25</td>
<td>0.28</td>
</tr>
<tr>
<td>Highway</td>
<td>0.77</td>
<td>0.97</td>
<td>0.64</td>
<td>0.71</td>
</tr>
<tr>
<td>Railway</td>
<td>0.60</td>
<td>0.96</td>
<td>0.22</td>
<td>0.32</td>
</tr>
<tr>
<td>Parks</td>
<td>0.59</td>
<td>0.66</td>
<td>0.17</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Note: 1 - heating season; 2 - non-heating season.

Table 3. Sulfur dioxide concentrations in the ambient air of Moscow (mg/m³)

<table>
<thead>
<tr>
<th>Area</th>
<th>1956</th>
<th>1958</th>
<th>1960</th>
<th>1962</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Industrial</td>
<td>0.84</td>
<td>0.82</td>
<td>0.37</td>
<td>0.24</td>
</tr>
<tr>
<td>Residential</td>
<td>0.84</td>
<td>0.51</td>
<td>0.28</td>
<td>0.13</td>
</tr>
<tr>
<td>Highway</td>
<td>-</td>
<td>-</td>
<td>0.52</td>
<td>0.13</td>
</tr>
<tr>
<td>Railway</td>
<td>0.78</td>
<td>0.68</td>
<td>0.56</td>
<td>0.22</td>
</tr>
<tr>
<td>Parks</td>
<td>0.78</td>
<td>0.70</td>
<td>0.60</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Note: 1 - heating season; 2 - non-heating season.
Volgograd Oblast is a large industrial and agricultural area of the Povolžje region. The basic industrial branches in the area are metallurgy, machine construction, chemical industry, production of building materials and food industry. The major part of potential industrial air pollution sources is situated in and around the city of Volgograd and the town Volžkij.

The city of Volgograd - one of the largest industrial towns in the Oblast - is situated on the right bank of the river Volga and extends for about 90 kilometres along the river.

At the beginning of the twentieth century, the city of Volgograd (then called Caricin) represented a chain of settlements extending along the Volga but separated from it by railroads, warehouses and factories. The town used to be highly polluted by smoke and industrial gaseous effluents. However, the rapid growth of the new industry, accompanied by the construction of new residential districts and extensive sanitation works, completely transformed the town in the years preceding the Second World War. The town was completely destroyed during the war but the reconstruction of factories and residential quarters began as soon as the war operations moved further west.

Extreme shortage of accommodation necessitated the use of remnants of living quarters in the northern part of the town and consequently the sanitary protective zones around basic industrial establishments were consolidated on the same scale as before the war; this, of course, made the proper organization of zoning more difficult. The drawbacks in the planning of the town are now being rectified by improving the distribution of the residential districts, by creating green belts and by modernizing technological processes to reduce the emission of noxious substances into the atmosphere.

The Volgograd Sanitary-Epidemiological Station was organized in 1949 by merging the separate sanitary and epidemiological services. The Volgograd Sanepid Station has two departments: the Sanitary Department with divisions of municipal hygiene, industrial hygiene and sanitation, nutritional hygiene and school hygiene; and the Department for the Prevention and Control of Epidemics with divisions of epidemiology, parasitology, communicable diseases and disinfection. Each department has corresponding laboratories (municipal hygiene, industrial hygiene, toxicology, corrosive and poisonous chemicals, microbiology, virology, communicable diseases and parasitology). The departments and the corresponding laboratories operate as integrated units.

The Division of Municipal Hygiene is one of the main organizational units of the Sanepid Station; its objectives and methods of work are analogous to the same division in other sanitary-epidemiological stations, like the Moscow City Sanepid Station.

During the last few years significant measures have been undertaken in Volgograd for the sanitation of the air basin and for improvement in the town planning, which reduced considerably the levels of ambient air pollution. Only during the last five years, for instance, 174 gas cleaning installations were constructed and 35 domestic boiler rooms were modified for gas fuelling. On the proposal of the sanitary-epidemiological service, many gas cleaning installations were reconstructed and a number of research and development studies, aiming at the improvement of technological processes, gas purification and dust control devices, were initiated.
Taking into account the climatic conditions which make the cleaning of general ventilation gases even more difficult, the sanitary-epidemiological service charged the technologists of the Volgograd aluminium factory to change the production technology in such a way as to contain the emission of noxious gases and to carry out the cleaning of effluents in a central installation. Although the whole project has not yet been completed, the concentration of fluorine compounds in the atmosphere has been reduced about ten times. In many industrial establishments the effluent cleaning technology is being developed in parallel with the production technology from the outset of construction works. Examples of such methods of work are the Volgograd Gypsum Factory, the Mihajlov Cement Factory, the Volgograd Lamp-Black Factory, and others. Having in mind further improvement of the conditions of the air basin, the sanitary-epidemiological service, the Oblast Planning Department and the industry drafted a perspective development plan 1967-1970 which contains a detailed development programme for each industrial establishment and sets a fixed date for its implementation.

The new Volzkij town was planned, from the beginning of its development, in such a way that the industrial and residential districts were strictly separated. The industrial establishments of the town are collected in groups with common servicing. The principal potential air pollution source is the Volzkij Chemical Works where the problems of effluent cleaning have been solved from the beginning of construction. However, since a perspective development plan provided for the introduction of a new technological process that might discharge effluents for which the cleaning processes have not yet been worked out, a sanitary protective zone of five kilometres was established, separating the chemical industry district from the residential district. Following a plan proposed by the sanitary-epidemiological authorities, the Volzkij Chemical Works is solving such problems as the construction of burners for incineration of liquid organic effluents and of devices for purification of ventilation gases from rubber drying units; the utilization of hydrocarbon gases which are now burned in open flame, etc. The plants are equipped with special laboratories for checking the operation of gas cleaning devices.
CONTROL OF UTILIZATION OF INDUSTRIAL GAS CLEANING INSTALLATIONS IN THE USSR

by

A. G. Smirnov and V. V. Gagarinskij

There is a specialized organization in the USSR - the All-Union Association for Gas Cleaning and Dust Control (supervised and directed by the Ministry of Oil Refining and Petro-Chemical Industry) - which deals with various aspects of research, development and design of dust arresting and gas cleaning installations in different branches of industry. It comprises a Research Institute for Gas Cleaning (NIIOGAZ) as well as a Technical Inspectorate which collaborates closely with sanitary-epidemiological authorities. The Technical Inspectorate has its headquarters in Moscow but there are also several branch offices distributed throughout the USSR.

All installations for the control of dust and gas emission, as well as all technological gas purification appliances, are subject to regular supervision by the Technical Inspectorate. In the USSR no projects for erection or reconstruction of factories, special plants or units (if potential air pollution sources) are approved unless provision has been made for adequate control of gaseous wastes. If an expansion of production is contemplated, the efficiency of gas discharge control units is reconsidered and any problems which might arise are solved in compliance with the "Sanitary standards for the design of industrial establishments". The decisions and recommendations of technical inspectors are binding for all enterprises and organizations, no matter to which ministry or department they may belong.

The principal objectives of the Technical Inspectorate are: to inspect periodically the state of dust collecting and air cleaning devices; to supervise the construction and maintenance of such equipment; to see that the operating and safety instructions are followed and that the emission standards prescribed are obeyed.

The Inspectorate takes part in technical committees for pre-operational inspection and issues operation permits; prepares operating and safety instructions for gas cleaning devices, assists in solving problems related to safe and efficient operation of such devices; takes part in revising construction projects; and establishes performance specifications. A quarterly bulletin is published by the Inspectorate in which various activities of the Inspectorate are recorded. The bulletin contains results of various investigations, suggestions for new and more efficient methods for gas cleaning and describes better performance tests.

The Technical Inspector has a right to enter any industrial enterprise of any ministry or organization at any time and to inspect and examine gas cleaning installations; to request from the management that all records regarding performance of the equipment be submitted to him; to issue compelling instructions for removal of functional defects of the equipment; to demand that ministries of industry and other organizations prepare a perspective plan for air pollution abatement and present annual programmes for installation of gas cleaning equipment; to initiate legal prosecution of organizations, managers and other responsible persons if, as a

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a See the summary of the lecture delivered by Mr V. N. Uzov.

b By the Inspectorate; there are no emission standards established by the Ministry of Health.
result of non-compliance with instructions issued by the Inspectorate, excessive waste emission or accidents occurred; and to investigate damaged equipment or accidents involving gas cleaning and dust control equipment. If the state of gas cleaning installations is unsatisfactory or dangerous the Chief Technical Inspector may forbid further use of such equipment and, if necessary, even seal the main gas conduit.

Some industrial organizations have a special service for operation, technical inspection and maintenance of gas cleaning equipment. This service also carries out the relevant measurements on effluents to ensure that the emission of pollutants remains within acceptable limits.

Another duty of the Technical Inspectorate is to see that maintenance operations are performed regularly and in a planned manner. Before any gas cleaning installation is allowed to be put into operation after mounting or general maintenance, it is subject to systematic technical inspection and testing which includes estimation of its efficiency.\(^\text{a}\)

Each gas cleaning device must have an operating licence, issued by the Technical Inspectorate. Written instructions for normal operation and for emergency situations should be available and accessible to the operating personnel.

This brief description of the objectives of the Technical Inspection and its routine duties will be concluded by some statistical data on the growth of the number of gas cleaning installations in operation in the USSR (Table 1).

**TABLE 1. INCREASE IN THE NUMBER OF GAS CLEANING DEVICES AND ELECTRO-PRECIPITATORS IN DIFFERENT BRANCHES OF INDUSTRY**

<table>
<thead>
<tr>
<th>Branch of Industry</th>
<th>Relative number of gas cleaning installations</th>
<th>1960</th>
<th>1964</th>
<th>1965</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>All types</td>
<td>Electro-filters</td>
<td>All types</td>
</tr>
<tr>
<td>Chemical and oil processing industry</td>
<td>100</td>
<td>100</td>
<td>138</td>
<td>169</td>
</tr>
<tr>
<td>Metallurgy</td>
<td>100</td>
<td>100</td>
<td>110</td>
<td>139</td>
</tr>
<tr>
<td>Building materials</td>
<td>100</td>
<td>100</td>
<td>132</td>
<td>165</td>
</tr>
<tr>
<td>Power stations</td>
<td>100</td>
<td>100</td>
<td>110</td>
<td>129</td>
</tr>
</tbody>
</table>

\(^{a}\) The efficiency of dust arresters is estimated by one of the three equivalent equations:

\[
\eta = \frac{\text{amount of dust collected/hour}}{\text{amount of dust entering the device/hour}}
\]

\[
\eta = \frac{\text{difference between the amount of dust in the incoming and outgoing gas}}{\text{amount of dust in the incoming gas}}
\]

\[
\eta = \frac{\text{amount of dust collected}}{\text{amount of dust collected} + \text{amount of dust in purified air}}
\]
1. Marfenin, F. (1950) *Handbook of safety engineering and industrial sanitation*  
   Moscow, Profizdat (In Russian)

   Moscow, Metallurgizdat (In Russian)

3. Užov, V. N. (1964) *Safe operation of electro-filters in chemical industry*  
   Moscow, Himizdat (In Russian)
Meteorological Problems in Air Pollution Control
THE INFLUENCE OF METEOROLOGICAL FACTORS ON AIR POLLUTION
AND CALCULATION OF THE DIFFUSION OF ATMOSPHERIC POLLUTANTS

by

M. E. Berljand

The concentration of air pollutants discharged into the atmosphere by industrial plants varies considerably in space and time. If there is a fixed regime for waste discharge, variations in concentration are determined mainly by meteorological factors. The influence of meteorological conditions on the diffusion of atmospheric contaminants is of great significance in dealing with many practical problems (e.g., location of residential districts; development of methods to prevent pollution of the lower layers of the atmosphere; estimation of the necessary height of stacks). Many theoretical and experimental studies have recently been carried out in the USSR, at the Main Geophysical Observatory (A. I. Voejkov Observatory) in Leningrad in collaboration with a number of other institutes and organizations to determine the quantitative characteristics of the distribution of contaminant concentrations.1,2,3,4,5,6,12

The basis of the theoretical work is a solution of the differential equation for turbulent diffusion.7,9 The coefficients of this equation are the components of the turbulent exchange coefficient. They are functions of the altitude and, in case of uneven ground, they also depend on horizontal co-ordinates. In solving this problem it is of primary importance to determine the type of these functions and their dependence on meteorological conditions. Electronic computing methods were used in solving the differential equation.

The investigations showed that immediately above the stack the rise of the contaminants was proportional to the emission velocity of gases and to the temperature difference between the gases and the surrounding atmosphere. The initial rise of contaminants depends largely on wind velocity; at low wind velocities the rise is faster. Consequently the ground concentration should decrease with decreasing wind velocity. However, the wind does not influence the initial rise only; for a fixed height of discharge the concentration decreases with increasing wind velocity. Thus, the wind velocity influences the concentration in two different ways, and there is a so-called 'critical velocity' when the ground concentration attains its maximum value.

The maximum ground level concentration may be calculated from the following equation:

\[ C_M = \frac{AMFM^3}{H^2 \sqrt{V\Delta T}} \tag{1} \]

where \( N \) is the number of stacks, \( H \) their height; \( A \) is a coefficient determining the influence of the vertical and horizontal mixing in the atmosphere. Its value is determined for unfavourable conditions when the wind velocity has its 'critical' value and the turbulent exchange is intense; under these conditions the ground concentration attains its maximum value. The value of this coefficient varies for different climatic zones. It has a high value for southerly and forest regions which are characterized by an intense turbulent exchange in summer time. \( \Delta T \) is the difference in temperature of flue gases and the surrounding air; \( M(\text{g/sec}) \) and \( V(\text{m}^3/\text{sec}) \) denote the mass of the contaminant and the volume of flue gases discharged per unit time, respectively. \( F \) and \( m \) are dimensionless coefficients, the value of which depends on the settling velocity of the contaminant and discharge characteristics of flue gases from the stack, respectively. The 'critical' velocity is given by:
\[ u_M = 0.65 \sqrt{\frac{3V \Delta T}{NH}} \] (2)

and its value can vary significantly. For instance, for a thermal power station \( u_M = 5 \text{ m/s} \) and for some chemical plants \( u_M = 1-2 \text{ m/s} \).

In the direction of wind the maximum concentration is attained at a distance \( x_M \) equal approximately to 20 \( H \). The ratio \( x_M/H \) increases with increasing height of the stack. Calculations show that at the 'critical' velocity of the wind, the ratio \( c/c_M \) attained at a distance \( x \) from the stack depends, approximately, only on \( x/x_M \) (Fig.1). The curves showing the dependence of \( c \) on \( x \) are asymmetrical. As \( x \) increases the concentration \( c \) first increases sharply reaching a peak value and then declines gradually. The asymmetry of the curve depends on the height of the stack (Fig.2). For high discharge points the decrease of \( c \) with \( x \) after the peak is more gradual. As the height of the discharge point increases, the degree of air pollution decreases considerably, but the contaminant concentrations remain stable even at large distances from the stack. It is important to give due consideration to this effect when determining the background pollution at sites where new plants are built or old ones reconstructed.

With increasing distance \( x \) the transversal distribution of the concentration, \( c_y \), becomes more uniform decreasing slowly from the axis of the plume to the periphery (Fig.3).

The concentrations in the above equations refer to a 20-minute sampling time. In deriving the formula for \( c_M \), consideration was given to the change of wind in horizontal direction during a given period of time. If the sampling time is reduced, the average amplitude of the wind-turning angle in the horizontal plane is reduced and consequently the concentration at the axis of the plume will increase, and the decline from the axis to the periphery will be steeper. On the contrary, if the sampling period is extended the amplitude of variation of wind direction increases, the peak concentration is reduced and the distribution of concentrations in the transversal direction becomes more uniform. That is the reason why 24-hour average concentrations measured at a given point in the polluted area are significantly lower than the maximum single concentrations. Correspondingly, there are also two indices of air pollution, the maximum permissible single exposure concentration (referring to a sampling period of 20 minutes) and 24-hour average maximum permissible concentrations.

In designing air inlets to industrial and other buildings it is important to know the vertical distribution of contaminant concentrations (Fig.4). Close to the source the distribution is fairly symmetrical in relation to the axis of the plume; the highest concentration is attained at the axis of the plume, while above and below it the concentrations gradually decrease. Moving away from the source, the axis of the plume drops down and at a certain distance the maximum concentration is attained at ground level. With increasing height from the ground the concentration of the contaminant decreases, first slowly and then very sharply. These results apply to comparatively frequent meteorological conditions characterized by a decrease of temperature with altitude, and by an intense turbulent exchange favouring the transport of contaminants to the ground layers of the atmosphere. With regard to the wind velocity, it has been assumed that it changes with altitude according to a logarithmic law.

In some anomalous cases the concentrations of contaminants may differ essentially from those already described. Such is the case, for example, when there are elevated temperature inversion layers in which the turbulent exchange is reduced, making the transport of contaminants difficult. According to our calculations, if such temperature inversion layers
are situated immediately above the pollution source, the pollutant concentration may increase significantly. A significant increase of concentration with distance can be noticed also when wind velocity sharply decreases to zero values at ground level, with developed turbulent exchange (Fig.6).

It should also be pointed out that temperature inversion conditions immediately above the stack cause a decrease in the initial uplift of contaminants, especially if the flue gases are cold. This increases the concentration of the contaminant even more, and if the wind velocity is low the concentration can sometimes attain very high values.

The irregularities of the terrain may have a significant influence on the diffusion. The nature of air movement changes considerably if the ground is uneven. There is a slowing down of wind in depressions, and sometimes the air movement stops. The distribution of concentrations becomes much more complicated. The application of modern theoretical methods of research has provided an approach to a solution of this difficult task. Calculations are at present being made relating to some examples of hilly terrain with comparatively small irregularities of the relief. The results show that the maximum ground level concentration is usually higher than for a flat landscape, all other factors being nearly the same (Fig.7).

In the case of gently sloping forms of relief, there is practically no change in concentration distribution as compared with flat terrains.

For an understanding of the peculiarities of wind distribution over complicated forms of relief, the microclimatic studies now carried out in natural and laboratory conditions, including experiments on relief models in aerodynamic tunnels are invaluable. Studies concerned with considerably polluted atmospheres, the distribution of contaminants in the presence of fogs, near water bodies, etc., have also been undertaken.

In collaboration with the Erisman Institute of Hygiene in Moscow, and with some other organizations, the Main Geophysical Observatory carried out a number of field experiments. The result of these observations are closely in agreement with basic conclusions from theoretical work (Fig.8). On the basis of these studies a provisional method for determination of diffusion of effluents from power plant stacks was proposed.13
REFERENCES


10. Berljand, M. E. et al. (1963) *Meteorologija Gidrol.*, No. 8


Fig 1  Longitudinal distribution of concentrations
x = downwind distance from source
x_M = downwind distance at which maximum concentration occurs
solid line - gas concentration
dotted line - ash concentration

Fig. 2  Longitudinal distribution of concentrations for two different source heights (H)
a: H = 50 m  b: H = 150 m
Fig. 3  Lateral distribution of concentrations at two downwind distances (x) from the source

\[ y = \text{lateral distance from the vertical plane through the stack or source and parallel to mean wind direction} \]

\[ a: x = 1 \text{ km}; \quad b: x = 3 \text{ km}; \quad 4: x = 5 \text{ km} \]

Fig. 4  Vertical distribution of concentrations at three different downwind distances (x); z = height above ground (in m); H = 100 m
Fig. 5  Effect of vertical distribution of exchange coefficient \( K_2 \) on longitudinal distribution of concentrations;
\[ H = \text{source height} \]

Fig. 6  Effect of vertical wind speed \( u \) distribution on longitudinal distribution of concentrations
Fig. 7  Effect of topography on longitudinal distribution of concentrations
1 - flat area
2 - stack at the foot of a windward slope
3 - stack at the foot of a leeward slope

Fig. 8  Concentrations as a function of stack height
\( c_M = \) maximum concentration (mg/m³)
\( M = \) mass emission rate of pollutant (g/sec)
• - computed  a: \( SO_2 \) - concentration
○ - observed  b: ash concentration
Criteria and Guides to Air Quality
WHO AND CRITERIA FOR AIR QUALITY

by

V. B. Vouk

One of the first steps in air pollution control is the measurement of levels of pollution; but measurement itself is only one part, although an essential one, in the evaluation of air pollution hazards. Some numerical values should be available for the maximum acceptable emission or ambient pollution levels, so that the person in charge of air pollution control knows whether control methods are adequate. This need for air quality standards was recognized by WHO at the outset of its work on air pollution. In the Fifth Report of the Expert Committee on Environmental Sanitation, which met in 1957, immediately after the Conference on Public Health Aspects of Air Pollution in Milan (November 1957), the problem of setting up air pollution standards was briefly discussed. The Committee concluded that "in spite of this natural desire (to have standards) and of the need that the legislation should be precisely directed - so that there is no doubt as to what emissions and what atmospheric pollution will not be tolerated by law - when it comes to establishing standards, there is a danger in writing specific figures into legislation because (a) industrial and technical performance is continually changing, causing standards to become outdated, and (b) a fixed standard for industrial operations can fail to take account of complexities in industrial development, so that a situation could arise where a rigid legal standard could result in the legal prevention of desirable industrial progress because of a technicality". The Committee recommended that "the standards of performance for the purpose of controlling the emission of pollutants should not be written into legislation, but should be incorporated in the form of regulations, capable of being altered by the administrative group without necessitating return to the legislature for authority". The Committee also thought that the principle to use the "best practicable means" to control the emission of pollutants a very sound one, because it implies that the standard for emission will automatically be lowered to a new level as soon as this becomes technically feasible. The existing legislation and air pollution standards were also reviewed by Parker in the monograph on Air Pollution, published by WHO in 1961. In this review it appears that the USSR was the only country which at that time had standards for air quality. Parker lists the maximum permissible pollution levels of 16 substances which were adopted in 1956 as standards of air quality in the USSR.

The subject of air quality standards was taken up again by the Symposium on Epidemiological Aspects of Air Pollution organized in Copenhagen in December 1960 by the WHO Regional Office for Europe. In the report on that Symposium we read that "the results of epidemiological research may have important application in the control of noxious pollutants. The observed diurnal relationship between disease and such indices of pollution as the sulfur dioxide content of the atmosphere or the concentration of suspended matter suggests the possibility of defining a minimum standard of air purity. This limit might be that concentration of an agreed pollutant below which changes in morbidity and mortality are not demonstrably related to changes in the concentration of the pollutant".

The subject of air quality standards was first fully discussed during the Eighth European Seminar for Sanitary Engineers organized by the WHO Regional Office for Europe in Brussels (1962). This was also the first time that Soviet experts attended a WHO meeting on air pollution. In a paper entitled Criteria and Methods for Establishing Maximum Permissible Concentrations of Air Pollutants, Professor Rjazanov described the Soviet approach in establishing air quality standards. The attitude of Soviet workers in the field of environmental hygiene is that only such concentrations of air pollutants which do not directly or indirectly exert harmful or unpleasant effects on man, reducing his working capacity, or having a negative effect on his physical or mental well-being, can be accepted as permissible. Professor Rjazanov described standards based on this principle as hygienic standards. They
should be regarded as ideals towards which we must strive. Until they are reached there must be temporary sanitary standards depending on the conditions prevailing in a country. They may differ from country to country as they have to take into account the internal economic structure. There may also be technological standards the purpose of which is to prevent uneconomic waste of material. Such standards have nothing in common with hygiene and are based on economic and technological considerations. According to Professor Rjazanov, the hygienic standards should be based on experimental toxicological evidence rather than on epidemiological studies, since data derived from epidemiological studies tell us which concentrations are harmful rather than how low a concentration should be in order to be harmless. Professor Rossano's paper described the US approach to the problem of air quality standards. In terms of USSR terminology, the California standards are sanitary rather than hygienic. Such standards depend on local conditions, and the level at which they are set is a compromise between numerous factors including technical and economic feasibility of control and the preferences, requirements and demands of the local community, as well as the health and welfare of the public.

The air pollution legislation was surveyed again in 1963 in a WHO publication in which pertinent legislation in 13 countries was reviewed. Two extreme attitudes could be found: one was to try to control air pollution "by use of the best practicable means", i.e. taking into account the available technological means and the economic factors involved; the other was based on the principle that any pollution of the atmosphere liable to produce harmful effects or nuisance had to be prohibited.

A big step forward towards the solution of the problem of air quality standards was achieved during the Inter-Regional Symposium on Criteria for Air Quality and Methods of Measurement held in Geneva in August 1963. The discussion showed that there were many similarities in the approaches to air quality standards adopted in different countries and that many apparent differences were, to a large extent, due to the terminology used. The Symposium succeeded in agreeing on many important aspects of air quality standards, such as the rationale for selecting air quality criteria, on the role of epidemiological and aerometric surveys and the medical studies needed for the improvement of data relating to guides to air quality. The Symposium also stressed the need for standardization of methods of sampling and analysis of ambient air pollutants, as well as the need for international collaboration and agreement on air quality criteria and methods of measurement, but the numerical data that might serve as guides to air quality for specific air pollutants were not considered.

The main conclusions of the Symposium were endorsed by the WHO Expert Committee on Atmospheric Pollutants which met soon after the Symposium:

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

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

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

   Level I (level of detectable effect). Concentration and exposure time below which, according to present knowledge, neither direct nor indirect effects (including alteration of reflexes or of adaptive or protective reactions) have been observed.
Level II. Concentrations and exposure times at and above which there is likely to be irritation of the sensory organs, harmful effects on vegetation, visibility reduction, or other adverse effects on the environment.

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

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

For some known pollutants, it may not be possible to state concentrations and exposure times corresponding to all four of these levels because (a) the effects corresponding to one or more of these levels are not known to occur with the substance in question, or (b) exposures producing effects corresponding to certain levels also produce more severe effects, or (c) the present state of knowledge does not permit any valid quantitative assessment (e.g., of threshold levels for carcinogenic substances).

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

By adopting these definitions and principles a common language was found and the differences between the 'pragmatic' approach (adopted notably by USA and England) and the 'hygienic' approach (adopted by USSR, Czechoslovakia and Poland) were largely removed. The 'hygienic' standards correspond to level I while the 'sanitary' standards should be set somewhere between levels I and II. The Symposium also agreed that the scientists should produce basic information for determining the potential for damage of different air pollutants, and advise on criteria to be used, but that the governments should adopt standards. In other words the standards are guides to air quality which have legal power because they have been adopted by authorities.

Since one of the main obstacles in setting up internationally acceptable air quality guides is insufficient knowledge of the dose-response relationship for different air pollutants, the Symposium was of the opinion that a variety of medical studies was needed to obtain more reliable data relating to guides to air quality.

The research required to improve air pollution control measures was discussed by the Scientific Group on Research into Environmental Pollution. The development of internationally acceptable guides to air quality has been recommended as one of the topics where further applied, as well as basic, research is needed. Among the long-term research programmes the Scientific Group included many studies which would improve knowledge on the nature of air pollution and its relation to the biological effects, such as the action of air pollutants on the central nervous system and the autonomic nervous system, biochemical responses to air pollution, the effects of air pollutants on respiratory functions, immunological reaction to air pollutants, air pollution effects on plants and domestic animals, field studies on the relation of repeated irritation to the production of chronic disease and life shortening, and many other studies.

The aim of air quality guides is to prevent short-term, as well as long-term effects of air pollution on health and well-being of individuals and populations. The short-term harmful effects are produced by much higher concentrations, comparable to those encountered in industry, and the relationship between the cause and effect should not be too difficult to establish. The difficult problem to solve is the setting up of such air quality guides that the probability of occurrence of long-term effects is minimized. This problem was studied by the Scientific Group on Long-Term Effects on Health of New Pollutants which was convened in Geneva in
November 1964. Among other things the Group concerned itself with "methods and procedures which provide a scientific basis for regulations to prevent the long-term health effects of pollutants in air and water". The problem of long-term effects is very complex because there is a large variety of possible effects and mechanisms producing the effects (effects due to accumulation or storage of pollutants in the body; delayed effects of comparatively high-level brief exposures; contributory role of pollutants in pathogenesis of a chronic disease, ageing and life-shortening; irreversible, prolonged or repeated impairment of important functions of the body; genetic effects) and because the effects are mainly non-specific. Safe levels of pollution can be set, in principle, because there is a threshold below which no detectable effects occur within the normal life-span; the possible exceptions are substances causing mutagenesis, teratogenesis or carcinogenesis. The Group pointed out that more basic knowledge is needed about absorption and distribution of toxic substances, and about their metabolism, storage and excretion if we want to develop better criteria for public health regulations. The Group also warned that no general extrapolation of industrial air quality guides to community air quality guides should be attempted because exposed populations differ greatly. With regard to carcinogenic substances, the Scientific Group thought that the assumption of no threshold is perhaps too conservative, and that more experiments involving large groups of animals are needed to assist the establishment of safe exposure levels.

Standardization of terminology, units, methods of measurement and of reporting results is one of the prerequisites for formulating internationally acceptable air quality guides. A Scientific Group on Identification and Measurement of Air Pollutants (Geneva, November 1965) was formed to study this problem. Among other things it stressed the need for widespread and frequent measurement of individual pollutants, and combinations thereof, for the purpose of establishing criteria and guides for air quality.

This summary of WHO's work on air pollution criteria and guides is by no means exhaustive. Much useful information on the subject can be found in reports of various other WHO committees and scientific groups not directly concerned with the problem, for example the Report on Microchemical Pollutants in the Environment and the reports of the WHO Expert Committee on Radiation.

Thus it seems that a large part of preliminary work needed for recommending internationally acceptable air pollution criteria and guides has been accomplished.

The general principles have been agreed upon and endorsed by a WHO Expert Committee, and a guide for selection of methods for measuring air pollutants has been prepared. There remains only one step - a very difficult one - and that is to see if general agreement among experts and scientists concerned can be achieved to establish criteria and numerical guides for air quality. Since at least eight countries have already adopted air quality standards for selected air pollutants, there seems to be no real obstacle (in the opinion of the lecturer) to setting up provisional criteria and guides for a limited number of the most common air pollutants. Surely authorities and those in charge of air pollution control in different countries will agree that it is better to have some criteria and guides, even if they are far from perfect, than to have none at all. They should be of temporary character subject to periodic revision but, and this is very important, they should be realistic and attainable by the technological methods and financial means available, even in developing countries. The history of the ICRP shows that this is possible. The first radiological protection standards were set when our knowledge of the biological effects of ionizing radiation was much scantier than is the present knowledge of many air pollutants.
REFERENCES


8. World Health Organization, Scientific Group on Research into Environmental Pollution (1964) Report to the Director-General, PA/236.64, Geneva (mimeographed)


Hygienic standards are numerical indices of environmental conditions that are biologically most favourable to human existence.

Every living organism requires certain environmental conditions for its existence (availability of the necessary food, certain meteorological conditions, etc.). Only if these conditions are in accordance with the hereditary factors, i.e. the specific requirements of the organism, will they form a wholesome living environment best suited to the given form of life. That is the reason why optimum biological conditions differ for every animal species; these differences may be very great. For instance, some living organisms need oxygen permanently while other species cannot live if oxygen is present; for one species oxygen is a necessary condition of existence, for another it is a poison.

The closer living organisms are to each other from the evolutionary point of view, the closer they will be in their environmental requirements. In this sense the mammals, in particular monkeys, are very close to man. Consequently animal experiments are widely used in medicine for studying the biological properties of the human organism. However, the differences between man and animals, even those that are closest to him from the evolutionary point of view, are so great that animal experiments must always be supplemented by observation on human subjects to determine those peculiarities which are characteristic only for man. As is well known such a peculiarity is the second signalling system, i.e. communication by speech which is absent in animals and is a characteristic feature of human existence. The second signalling system makes man sensitive to psychogenic environmental factors to which animals are completely indifferent but which are of primary importance in normal human life as well as in human pathology.

Pathogenic factors occupy a special place among environmental factors since any environmental factor can become pathogenic if its intensity, its duration, or both, exceed certain levels. The threshold of pathogenicity depends on many conditions, the effect of which determines the stability of the organism in respect of environmental factors, such as the physiological state of the organism, previous diseases, emotional make-up, age, sex, hereditary characteristics, the presence of various additional environmental factors, which may be favourable or unfavourable, etc. The threshold is, therefore, not a constant value but varies considerably in different people at one period of time and in one person at different periods of time. Thus certain environmental factors may be pathogenic agents but they may also be promotors or inhibitors of other causative factors. Moreover, depending on circumstances, environmental factors may have favourable or unfavourable effects on the organism in relation to its general vitality. Unfavourable factors may have a negative influence on man's working capacity, on his emotional stability or on his feelings, without provoking any obvious pathological phenomena. The only environment which can be considered as biologically optimal is one that does not produce any pathological effects, or promote other pathogenic factors; does not affect man's emotional stability, his sensations or his working capacity; but secures good health and physical and mental well-being.

What is the essence of the biological optimum of the environment in relation to man? This question has to be answered by hygiene; it is its fundamental objective. The answer consists of the total sum of hygienic standards. Consequently, hygienic standards are not arbitrary values of certain environmental factors or arbitrary rules of human behaviour; they are scientific propositions based on the study of interaction between the organism and the environment, manifestations of objective laws of nature which cannot be invented but only discovered by studying the reactions of man and human groups to single environmental factors.
or their combinations under different conditions, taking into account various hereditary and acquired characteristics of man.

Consequently, arbitrariness, economic considerations, questions of technological feasibility, etc., are alien to the very nature of hygienic standards and cannot be taken into account when such standards are being established.

'Hygienic' standards must be distinguished from 'sanitary' standards. Hygienic standards represent optimum conditions towards which we must strive although we know that they are not always and everywhere attainable. Sanitary standards are, on the other hand, today's standards, which take into account technological feasibility and economic justifiability. In other words they represent a compromise between science and practice and are necessarily provisional. As the economy and technology of a country develop and the national income increases, the sanitary standards must be revised periodically and brought closer and closer to the hygienic standards.

Hygienic standards can often be the same for all countries because they are based on universal scientific data. Sanitary standards, on the contrary, may vary in different countries; what is attainable in highly developed countries may not, at the given moment, be a realistic possibility in a developing country.

The establishment of hygienic standards is a complicated and responsible task, and requires complex investigations. By experiments on animals and by observation of human subjects it must be shown which intensities of a given factor and which times of exposure at a given intensity, are harmless to man; it has to be proved that they do not cause disease and that they do not promote the effects of other factors. It has also to be shown that certain intensities of, and exposure times to, a given factor do not disturb physiological comfort.

What is hygienic comfort? First of all, under conditions of hygienic comfort we have no unpleasant sensations. A comfortable environment is one that is preferable to any other. Therefore, in investigating conditions of comfort the subject is taken from one set of environmental conditions to another, and his subjective sensations are recorded. In spite of apparent subjectivity, this has been found to be a very satisfactory and reliable method providing that conscious or unconscious deception is taken into consideration and controlled.

The second characteristic of comfort is the absence of any strain of adaptive mechanisms. If it can be shown that a given factor provokes mobilization of adaptive mechanisms, the environment is certainly not in a state of biological optimum.

The third characteristic of comfort is the absence of any constraint on freedom. Any change, including a change that is supposed to be pleasant, becomes unpleasant, unbearable or even harmful if it is forced on the organism against its will. Even music, if it is imposed on an individual when he does not want to listen to it, becomes an irritant restraining the freedom of will, and its effect is, therefore, unfavourable.

These are fundamental concepts in hygienic standardization of environmental factors. Examples from various fields of municipal hygiene are described.

As is well-known, a large amount of work has been devoted in the USSR to the problem of setting standards for ambient air quality, and maximum permissible concentrations have been established for 96 substances. In setting up these standards the effects of chronic exposure to toxic substances have been studied in animal experiments. The animals were exposed continuously for two to three months in exposure chambers where the concentration of the substance studied could be maintained at the desired level. The concentration levels were checked systematically by appropriate analytical techniques. These investigations showed that most of the chemical compounds studied were more toxic than was expected on the basis of previous experiments. Biological effects were observed at concentrations significantly below the maximum permissible concentrations (MPC) for industrial exposure. For example, in the
United States of America the MPC of lead for industrial exposure is set at 200 \( \mu g/m^3 \), and in the USSR at 10 \( \mu g/m^3 \). The investigations carried out by Gusev\(^1\) showed that even concentrations of 10 \( \mu g/m^3 \) cause obvious health disorders in experimental animals and in human populations. It has been established that this concentration impairs conditioned reflexes, leads to accumulation of lead in the skeleton and increases excretion of coproporphyrin in urine. Hence, this concentration is above the permissible level for the ambient air. Only concentrations below 1 \( \mu g/m^3 \) can be regarded as harmless for all members of the public. For this reason the maximum permissible concentration for lead in ambient air has been set at 0.7 \( \mu g/m^3 \) in the USSR. The industrial hygiene MPC for mercury is set at 100 \( \mu g/m^3 \) in the United States of America while the USSR standard is 10 \( \mu g/m^3 \). Experimental work of Kurnosov\(^2\) showed, however, that concentration of the order of 2 to 5 \( \mu g/m^3 \) damaged the conditioned reflex activity of experimental animals. Only concentrations below 0.3 \( \mu g/m^3 \) do not produce any effects; hence 0.3 \( \mu g/m^3 \) has been established in the USSR as the daily average MPC for long-term exposure.

In establishing hygienic standards in the USSR great value is attached to the subjective appraisal of the environment by members of the public, the users of urban air and water, the inhabitants of residential quarters, etc. The concept of 'comfort', which is indispensable in setting up hygienic standards, implies that subjective assessments of the environment should be taken into account - the wish to breathe air which one likes, to drink water which has a good taste, to maintain such temperature as is pleasant in the home - otherwise investigations of the effects of environmental factors on man would be meaningless. It is obvious that a given set of experimental conditions will provoke different subjective sensations in different people, and what may seem pleasant to one individual, may be unbearable to another. Hence one of the main hygienic requirements with respect to the environment is that man should be given the opportunity to change individual factors of the environment according to his wishes, to adjust them in accordance with his mood and his needs at a given moment. Any constraint of man's will, not originating from unavoidable and indispensable requirements, will have an extremely unfavourable physiological effect. There is an inborn instinct of freedom or, as Pavlov called it, the 'freedom reflex'. If such a reflex did not exist and animals did not strive towards freedom, biological progress and even the very existence of life would have been impossible. The inborn instinct of freedom is the subconscious basis explaining why unjustified interference with freedom becomes so unpleasant an experience. Thus, the freedom of choice is one of the main requirements which man has with regard to a comfortable environment.

The so-called psychogenic factors play an immense role in man's physical and emotional life. Modern hygienists must take this into consideration, and always try to protect the individual from the effects of harmful psychogenic factors. Soviet hygienists devote much attention to this problem; it is one of the reasons why so much work has been put into the scientific study of odours as irritants of the olfactory receptors of the nose. Research into these problems revealed that many malodorous air contaminants cause at the same time various reflexatory reactions such as changes in the frequency and the depth of breathing, contraction of skin capillaries, bronchial spasms, changes in the sensitivity of the eye to light, etc. Inhalation of such substances may also induce changes in the bio-currents in the brain, the formation of the so-called electrocortical conditioned reflex, or changes in the ability of the cerebral cortex to accept an imposed rhythm of fluctuations in light intensity. Another interesting fact also disclosed was that at very small concentrations of some chemical substances, these reflex reactions arise subconsciously. Subsensory reflex reactions are considered impermissible from the hygienic point of view. This is an example of the stimulation of the central nervous system not only without agreement but also without conscious participation. Nobody can accept this as ethically justified.
REFERENCES


EXPERIMENTAL METHODS FOR DETERMINATION OF MAXIMUM PERMISSIBLE CONCENTRATIONS OF ATMOSPHERIC POLLUTANTS

by

V. A. Čižikov

There are several approaches to the establishment of standards of ambient air quality. Soviet hygienists consider that hygienic standards should be based on the appraisal of the effects of air pollution on health, on man's working capacity and on his mental well-being. The presence of air pollutants is permitted only in such concentrations that do not directly or indirectly exert either a harmful or unpleasant effect on man, reduce his working capacity, or have a negative effect on his mental well-being. If this approach is adopted, all concentrations of noxious substances that have an unfavourable effect on vegetation, local climate, visibility and living conditions in general, are not permissible.

Two indices of the degree of air pollution are used in the USSR: the maximum permissible concentration for single short-term exposure and the maximum permissible daily average concentration. The purpose of the maximum permissible concentration for a single exposure is to prevent such pollution of the ambient air that can provoke reflex reaction of the organism caused by irritation of the receptors of the organs of breathing, mainly the olfactory area of the nose. The objective of the maximum permissible daily average concentration is to prevent chronic resorptive effects of long-term inhalation of toxic substances.

Since it is necessary to determine both the maximum permissible concentrations for a single short-term exposure and the maximum permissible daily average concentrations, all methods used for establishing air quality guides can be conveniently divided into two corresponding groups.

The maximum permissible concentration for a single (short-term) exposure is usually determined first. Methods used in the USSR for that purpose include the determination of the odours and excitation threshold as well as the threshold of reflex effects which is estimated by pneumography, rheovasography, optical chronaxy, adaptometry and electro-encephalography.

The first problem to be solved in such investigations is how to maintain a stable concentration of the substance investigated. Soviet hygienists use a device which is based on feeding a given amount of the substance into a stream of air (Fig. 1); the advantage of this device is that apart from being able to maintain a constant concentration it makes it easy to change the level of concentration and, when necessary, to supply pure air to the subject.

The investigations usually begin by the determination of the odour threshold. The experimont is carried out on a group of healthy volunteers. The threshold value of the most sensitive person in the group is taken as the basis for setting up the maximum permissible concentration. It has been shown that the stimulation of the olfactory analyser and the sensory nerve-endings in the mucous membrane of the respiratory passages gives rise to a number of protective reflex reactions: the frequency, rhythm and depth of respiratory movements change. The breathing may become irregular or its frequency increased while the amplitude is simultaneously reduced. In most cases reflex changes in the respiratory movements take place only at or above the concentration levels which cause the subjective sensation of odour or irritation of the upper respiratory passages (Fig. 2).

---

1 Soviet hygienists...

2 The maximum permissible concentration for a single (short-term) exposure is usually determined first. Methods used in the USSR for that purpose include the determination of the odours and excitation threshold as well as the threshold of reflex effects which is estimated by pneumography, rheovasography, optical chronaxy, adaptometry and electro-encephalography.

3 The first problem to be solved in such investigations is how to maintain a stable concentration of the substance investigated. Soviet hygienists use a device which is based on feeding a given amount of the substance into a stream of air (Fig. 1); the advantage of this device is that apart from being able to maintain a constant concentration it makes it easy to change the level of concentration and, when necessary, to supply pure air to the subject.
Measurement of the optical chronaxie has been widely used as a method for determining the threshold of reflex effects. It has been shown that under the influence of the inhaled substance the chronaxie changes; as a rule it increases, showing a reduction in the excitability of the central nervous system. According to the fundamental laws of the physiology of the central nervous system, excitation of the cerebral cortex in one region can give rise to inhibition in other regions. Thus, excitation in the olfactory region provokes inhibition in the visual region, and the optical chronaxie becomes longer.

The data obtained by pneumography and optical chronaximetry have shown that the odour threshold is an important hygienic parameter, as it indicates not only the possibility of subjective perception of the effect of the inhaled substance but also the possibility of occurrence of such reflex reactions as changes in external respiration or, what is more important, changes in the functional state of the cerebral cortex which reduce its excitability.

Atmospheric pollutants may also affect the peripheral blood circulation. Such effects have been investigated by means of rheovasography, which consists of measuring the resistance of a given part of living tissue to a high frequency electric current. The resistance is determined by the amount of blood present in the tissue and by the rate of blood flow. The higher the rate of change of blood flow, the higher the rate of change of resistance to the electric current. Thus, a rheovasogram reflects the haemodynamics of the tissue. At a certain concentration of the noxious substance in the inhaled air a significant change in the dynamics of the peripheral blood flow becomes noticeable.

The adaptometric method has also proved very useful in establishing the threshold of reflex effects of noxious substances. The light sensitivity of the visual system gradually increases while the subject remains in darkness (Fig. 3). If the subject is allowed to inhale a mixture of air and the substance investigated, the time-change of light sensitivity becomes different when a certain threshold concentration has been exceeded. The lowest concentration which causes a statistically significant change in the trend of light sensitivity is considered as the threshold value. In the course of studies on darkness adaptation it was noticed that changes in light sensitivity were provoked by substances in concentrations which were not perceptible by odour. This fact is of great significance in hygiene. It leads to the conclusion that we should not be satisfied by demanding that the concentrations of noxious substances in the ambient air remain below the odour threshold. Concentrations must not only be below the odour threshold but also below the threshold of subsensory subconscious reflex reactions, capable of changing the functional state of the central nervous system.

In their research on the effects of air pollutants, Soviet hygienists have widely used methods based on the recording of changes in the electrical activity of the cerebral cortex under the influence of small concentrations of noxious substances. The cortex of the brain continuously produces 'spontaneous' electrical fluctuations, in particular the so-called 'alpha-waves' with a frequency of 10 cycles per second and a comparatively high voltage (about 500 micro-volts). Alpha-waves are mainly connected with the activity of the visual zone of the cortex and disappear if the eye is illuminated or if the sight is fixed at a certain object. Buštuėva first pointed out that a de-synchronization of the alpha-rhythm may occur following a short term exposure to sulfur dioxide concentrations which are below the odour threshold. Since then, the so-called electrocortical reflex method has been widely used because it shows fine functional changes in the cerebral cortex under the influence of inhaled substances. If the inhalation of a substance is accompanied by a light stimulus (which is an unconditional stimulant inhibiting the alpha-rhythm), a 'conditioned' electrocortical reflex gradually develops, consisting of the appearance of inhibition or de-synchronization of the alpha-rhythm under the influence of the investigated substance alone (Fig. 4). By gradually
decreasing the concentration of the substance a limit is reached below which it is not possible to develop the conditioned reflex. There are also other methods based on electro-encephalography, for example the quantitative estimation of the electrical energy of the cortex in the course of simultaneous use of functional tests under tension. This method is based on a particular reaction of the cortex to a rhythmical light stimulation. In setting up the maximum permissible concentrations for a single (short-term) exposure all data supplied by toxicology and industrial hygiene are used. All experiments on human subjects are carried out only at such concentrations that have no effect on health.

The average daily maximum permissible concentrations are derived from specially designed animal experiments. For this purpose, animals are exposed 24 hours a day for two, three or five months in special chambers into which air, containing the investigated substance in given concentrations, is fed continuously. Such experiments simulate fairly adequately the conditions of exposure of man to the atmospheric environment of populated areas. As small concentrations are used, no noticeable changes are observed in the behaviour of the experimental animals and their weight shows no statistically significant difference from the control animals. Nevertheless, clear functional changes occur, as determined by objective methods. These methods will be briefly described.

Great significance is attached to chronic changes in the higher nervous activity of animals under the influence of toxic substances in the inhaled air. The leading Soviet hygienists believe that functional changes in the cortex of the cerebral hemispheres occur before any other changes since the cerebral cortex is highly sensitive to the effects of various environmental factors. Several methods are used to detect functional changes of the central nervous system, the most important being the study of conditioned reflexes. In assessing the functional changes of the cerebral cortex the chronaxies of the antagonistic muscles are also measured. While the absolute length of the chronaxie depends both on the central and the peripheral phenomena, the ratio of chronaxies is determined exclusively by central effects. The change in the ratio of chronaxies of antagonistic muscles can be interpreted as a weakening of the subordinating effects of the central nervous system due to protective inhibition (Fig. 5).

The stimulatory and inhibitory processes in the organism are closely connected with the function of the mediators, in particular with the activity of the cholinesterase which plays an important function in the transmission of nerve impulses. Significant changes in the activity of this enzyme give evidence of significant functional changes in the organism caused by chronic intoxication. The determination of cholinesterase activity in whole blood was one of the first biochemical methods used in the establishment of hygienic standards (Fig. 6). The number of biochemical methods applied in this field is increasing every day. A sensitive method for studying chronic intoxication of animals by atmospheric pollutants is the determination of the coproporphyrin in urine (Fig. 7).

The dynamics of metabolic processes can be studied by determining the protein fractions in blood serum, and sulph-hydryl groups in whole and de-proteinized blood (Figs. 8 and 9). In the course of intoxication of animals, the ratio between the low molecular (albumins) and the high molecular (globulins) proteins changes; the content of albumins decreases while the content of globulins increases. Although unspecific, this change in the molecular weight of serum proteins can be regarded as an index of a disturbance in the stability of the internal environment of the organism which cannot be regarded as a normal phenomenon, particularly in view of its long duration.
Among numerous other methods used in studies on hygienic standards of the ambient air, the following should be pointed out: examination of the morphological composition of the blood, the content of haemoglobin and its derivatives, the content of vitamins in internal organs, the content of vitamins in tissues, excretion of ketosteroids in the urine, etc. These methods are generally known and there is no need to discuss them in detail.

All experimental results are subjected to statistical analysis. Deviations from normal values and all functional changes, as determined by the methods described, are regarded as protective adaptational reactions of the organism; they show that environmental conditions have deviated from the physiological optimum and have forced the organism to mobilize its protective adaptational mechanisms. Although these changes cannot be regarded as pathological in the proper sense of the word they do point out that the environment has become unfavourable, and they reduce the capacity of the organism to adapt itself to the effects of other factors which may call for a rearrangement of the protective functions in some other direction.
REFERENCES

1. Rjazanov, V. A. (1952) Basic principles of hygienic standardization of atmospheric pollutants (in Russian) In: Maximum permissible concentrations of atmospheric pollutants, Moscow, Medgiz, 1.


Fig. 1  Experimental arrangement for preparation and maintenance of known concentration of air pollutants
1 - air compressor; 2 - silica gel; 3 - copper spiral; 4 - activated charcoal; 5 - container with the pollutant; 6 - mixer; 7 - inhalation cylinders; 8 - exposure chamber; 9 - exposure chamber; 10 - flowmeters; 11 - flowmeters with capillary tubes; 13 - sampling tube; 14 - sampling tube

Fig. 2  Effect of different concentrations of CO₂ on the amplitude of respiratory movement. Carbon dioxide concentration
1 - zero (pure air); 2 - 0.1 per cent.; 3 - 0.5 per cent.; AB - inhalation period
Fig. 3 Sensitivity of the eye to light at different concentrations of formaldehyde in air. Formaldehyde concentration:
1 - zero (pure air); 2 - 0.07 mg/m³; 3 - 0.093 mg/m³;
4 - 0.20 mg/m³; 5 - 1.1 mg/m³
Fig. 4 Amplitude of the adopted alpha - rhythm at different concentrations of toluylene di-isocyanate in the inhaled air. Concentrations of toluylene di-isocyanate
1 - zero (pure air); 2 - 0.10 mg/m$^3$; 3 - 0.15 mg/m$^3$;
4 - 0.20 mg/m$^3$

The arrow indicates the inhalation period.
Fig. 5 Effect of toluylene di-isocyanate on the chromaxie of different groups of rats (chronic exposure)
Effect of toluylene di-isocyanate on cholinesterase activity of the blood of different groups of rats
k - control group;
Concentrations of toluylene di-isocyanate:
1 - 2 mg/m³; 2 - 0.2 mg/m³; 3 - 0.02 mg/m³;
AB - exposure period
Fig. 7  Effect of toluylene di-isocyanate on the level of coproporphyrin in urine (rats)

k - control group

Concentration of toluylene di-isocyanate:
1 - 2.0 mg/m³; 2 - 0.2 mg/m³; 3 - 0.02 mg/m³
Electrophoretic analysis of protein in serum of normal rats (prior to exposure)

Electrophoretic analysis of proteins in serum of rats after two months of continuous exposure to 2.0 mg/m³ of toluylene di-isocyanate
ODOUR EXPOSURE AND ANNOYANCE REACTIONS FROM CRAFT PULP OPERATIONS

by

Lars T. Friberg

With rising standards of living, exposure to malodours (e.g. from industries and motor vehicles) will be considered increasingly important. Industries as well as regulatory agencies will require methods for evaluating exposure to odours and also the annoyance reactions caused by this exposure.

The quantitative determination of malodorous air pollutants in the ambient air is complicated by the fact that their smells become offensive at concentrations which are too weak for the practical analysis of short-term measurements. This also holds true for the odorous sulfur compounds, hydrogen sulfide, methyl mercaptan, dimethyl monosulfide and dimethyl disulfide, emitted by sulfate cellulose plants.

The strength of smell of some of these sulfur compounds has been determined by threshold tests in laboratory experiments in various quarters. The results are summarized in Table 1, which shows that the threshold for methyl mercaptan is of the order of $10^{-3}$ to $10^{-7}$ mg/l and that for hydrogen sulfide it is $10^{-3}$ to $10^{-6}$ mg/l. There is a substantial divergence between the results obtained by different investigators, even for studies made in recent years.

This divergence may be ascribed in part to the lack of sensitivity in many of the physical-chemical measurements, which means that the concentrations for organoleptic exposure are often only calculated. Another reason is probably due to the variations in apparatus, methods and definitions of 'threshold'.

Not all of the chemical substances in the effluent from sulfate cellulose plants are known. Moreover, there may be an interaction among the different sulfur compounds with respect to the resulting strength of the smell. It has been demonstrated in other contexts that the resultant strength of smell when several odorous substances are mixed is not always a matter of simple addition; there may be an enhancement or a suppression.

A more practical approach would probably be to determine the smell, either of relevant emissions in ambient air or of the emission of the combined flue gases at the top of the stack, in conjunction with calculations of meteorological dispersion. This would give a measure of the relevant total exposure to odours at ground level at different distances from the source. Another method is to study the occurrence of odours in the ambient air around factories, with the aid of observers.

In environmental hygiene, the most important dimension of an odour is probably its acceptability, i.e. how many individuals are inconvenienced by the smell, and to what extent. In most cases, however, a quantitative measure of acceptability or the degree of offensiveness cannot be obtained. Consequently, the usual method has been to determine the odour threshold, which is done by studying the extent of the dilution required to reduce the concentration below the threshold of smell. The usual procedure is to establish the value at which only half the observers detect the smell. Some authors (e.g. Rjazanov), however, prefer to define the threshold as the value for the most sensitive of the subjects, while Meuly & Tremaine propose setting it where the subjects experience a distinct sensation of smell.

Several apparatuses for the organoleptic determination of odours have been designed since the end of the last century. A well-known technique is the Elsberg & Levy blast injection, which carries the odorous gas straight into one or both nostrils. Another principle involves the use of an exposure chamber, which has the advantage of having several subjects exposed simultaneously, and under identical conditions, to the same stimuli. On the other hand, the
large volume of air required makes it difficult to change the concentration of the substance rapidly, and consequently the utility of the method is limited in practice. In order to satisfy the need for natural inhalation conditions and still be able to effect rapid changes in the concentration, several researchers have chosen to use the smelling hood, which exposes only the face or the head. A variety of designs has been presented, for instance by Bozza in Italy, Sullivan, Adams & Young in the United States, and Cederlöf, Edfors, Friberg & Lindvall in Sweden.

The Swedish apparatus has been used repeatedly in direct field experiments with flue gases from two sulfate cellulose plants. These studies have had the following primary aims:

1. To study odour thresholds for flue gases and thereby obtain a measure of the strength at source and then, with the help of stack height, topographical and meteorological data, calculate the dilution with air that would be necessary to achieve an odourless state at ground level at different distances from the factory.

2. To study the relative importance of various odour-generating processes for the intensity of the odour of the final emission.

3. To study the effect of various types of odour-reducing systems.

No detailed account of the results will be given here. Some of them have already been published. The following examples will serve to illustrate various aspects of the method and its applications:

Fig. 1 shows the results from an investigation of six different gases - the effluent gas from the stack and certain other gases generated within the process. The figure also exemplifies the principle employed for evaluating the results.

The odour threshold was determined in principle by means of paired comparisons between fresh air and five different dilutions of the odorous gases. In other words each observer always compared two 'gases', of which one was always fresh air and the other one was a certain concentration of the flue gas. The odorous gas was always presented in an ascending order of concentration. The effects of anticipation were avoided by using a random sequence for the order in which the gas and the fresh air were presented each time. As soon as the observer had smelled the two 'gases' making up a pair, he formed a judgement that could later be classified according to the following alternative responses (Fig. 2):

1. Gases dissimilar, air smells.
2. No smell in either.

The first response, 'air smells', may be due to the observer's uncertainty or to an error in the dosage. The probability of such an error arising is, presumably, equally great for the first and the third responses, i.e., the 'air smells' and the 'test gas smells'. Consequently, a net response was calculated as the difference between the number of observations for these two responses. The net response may thus be taken as a quantitative expression for the degree to which the concentration in question could be detected by the observers. The threshold can be expressed numerically with the help of probit analysis as the dilution at which half the observers detected the smell.

The thresholds for the six gases are given in the figure. The gas from the top of the stack represents, in this case, the combination of the five constituent gases and is the main source to be considered from the point of view of environmental hygiene. It will be seen that the threshold lies at about $10^{-5}$ for this gas and varies between about $10^{-4}$ and $10^{-8}$ for the five constituent gases.
If allowance is made for the volumes of the constituent gases, these results will provide the starting point for an assessment of the environmental hygiene. This can be exemplified with the data from a new pulp mill which is being planned in Sweden. The mill will have a capacity of 200 000 tons of pulp per year, and will be located on the west coast of Sweden, near a city and a recreational area where exposure to odours must be avoided as much as possible. The plans for the factory include the installation of extensive equipment for odour control. Based on data from studies on stack-gases from similar mills, the odour threshold of the emitted gases can be expected to average $10^{-4}$. The height of the stack will be 120 m, and there will be an emission of 215 000 Nm$^3$/h of gases. Based on the prevailing meteorological situation in that part of Sweden, it has been possible to calculate the frequency with which the odour threshold in the ambient air will be exceeded at varying distances from the mill. The prognosis is given in Fig. 3. As can be seen, the odour threshold will, on the average, be exceeded only for about one hour per month, with the exception of the near vicinity of the mill. During exceptional conditions, values of two to three hours can be expected.

The effect of counter-measures was studied at another factory where black liquor oxidation, followed by chlorination in a scrubber, is used and the results are shown in Table 2. It will be seen that oxidation reduced the intensity of the odours by one power of ten and the chlorination by a further two powers of ten. However, the gases emitted from the scrubber in this case still had a threshold of between $10^{-5}$ and $10^{-6}$.

Chemical analyses of hydrogen sulfide, methyl mercaptan, dimethyl monosulfide and dimethyl disulfide have generally been made in conjunction with the threshold determinations, by the Swedish Water and Air Pollution Research Laboratory. One of the aims has been to study the relationship between the concentrations of these substances and the intensity of the odours, in order to try to find some substance or combination of substances that could be used as an 'index' for predicting the threshold.

As far as the gases from the digesters are concerned, the results have been disappointing and it seems that determinations of odour thresholds represent the only feasible approach at present.

The situation is somewhat different concerning the gases from the soda furnace, as may be illustrated by a comparative study of the soda furnaces at two of the factories. In both cases, chemical analyses indicated that hydrogen sulfide was the only one of the sulfur compounds considered that could be demonstrated. The correlation between hydrogen sulfide and the odour threshold is shown in Fig. 4.

In one case the correlation is extremely good and in the other one it is satisfactory. What is remarkable, however, is the difference between the slopes of the regression lines, which indicates that for both soda furnaces a high content of hydrogen sulfide gives a high odour intensity, whereas low hydrogen sulfide content gives a low intensity for one furnace only, the intensity for the other one remains high. This finding, combined with the otherwise negative chemical analyses, suggests that other substances are relevant for the threshold besides the conventional sulfur compounds.

From these results, it may be concluded that data are already available to show that organoleptic investigations can be of great importance for the community at large as well as for industry's plans and investments for air conservation.

Many basic theoretical problems remain to be solved concerning the neurophysiological and psychological background to olfactory perception. Other questions include the significance of the adaptation effect for the selection of exposure times and intervals between exposures, the variability between observers, the intra-individual consistency, the effect of various climatological, biological and psychological background variables and, last but not least, the relationship between odour intensity and acceptability. There is also the matter
of the principles for the selection of text subjects. Young, Adams, Sullivan & Dobbs considered some of these problems in a recent study. The odour threshold for hydrogen sulfide was studied in more than 3000 subjects from different age and sex groups, with certain environmental variables also taken into consideration. Although differences were found, they were relatively slight. This suggests that it may be possible, by using suitable selection techniques, to study comparatively small groups for the practical determination of odours.

Observers were used, in another way, to estimate the frequency and occurrence of odours in the ambient air around a factory, and they were also asked to estimate, approximately, the strength of the odour. Such observations can be made with either many untrained observers or with fewer trained individuals.

Horstman, Wromble & Heller used 100 untrained high school students as observers in a study of the occurrence of odorous air pollutants in two adjacent communities in the States of Idaho and Washington. The atmospheric conditions were relatively poor, due partly to the location of a sulfate plant in the neighbourhood. The students were instructed to record and classify the odours they detected by quality and origin and also to estimate the strength on a simple scale. Observations were made three times daily during fortnightly periods simultaneously throughout the district. The results revealed the geographical and temporal distribution of the odours emitted and their relative importance for the strength of smell. Sulfate smells were observed much more frequently, with a greater intensity and over wider areas, than were other odours in the same district.

In a recent Swedish study, of two months' duration, about 1000 observers were used and each one followed the same scheme. Each observer was instructed to record the awareness of odours in his neighbourhood for three consecutive days. Daily measurements of odour thresholds and the concentrations of sulfurous substances in the stack-gases were also performed in order to estimate in this way how often the concentrations of stack gases in the ambient air, at different distances from the mill, could be expected to exceed the odour threshold for the gases. This data has not as yet been processed in detail. However, it is obvious that the observers noticed the odour over longer periods and more frequently than should be expected when based on the emitted 'odour units'. Additionally, odours were observed more frequently while the observers were outdoors than when they were indoors. The reason for the discrepancy between the theoretically estimated frequencies and those actually found by the observers is not clear. However, it must be remembered that the estimation, based on odour thresholds of the stack-gases and meteorological dispersion, only mathematically summarizes the time when the concentration, at the specific locations, could be expected to exceed the odour threshold for the gases. It might well be that if the concentration of sulfurous compounds fluctuates closely around the odour threshold, these observers cannot differentiate this fluctuation but experience the odour as more permanent than it is de facto. As an example, let us suppose that an observer has indicated that he has noticed odour over a specific ten-minute period; he would probably have given this answer even if the concentration of stack-gases had been above the odour threshold for only every second or third half-minute during this period. In the example given earlier, where a prognosis has shown an expected concentration of stack-gases above the odour threshold in the ambient air for only two hours per month, it might well be that the population, so exposed, will experience an odour over considerably longer periods.

With regard to the response of the population to stack-gases from craft pulp mill operations, no serious health effects are known from the concentrations that occur in the ambient air. As was mentioned in the introduction, however, exposure to malodours must - with an increased standard of living - be considered more and more important. The author's opinion is that this exposure should be considered not only from the aesthetic and economic point of view, but also from the health aspects and should be evaluated in the same way as is the effect from exposure to aircraft noise and traffic noise. This opinion would be in agreement with the views expressed in the Constitution of the World Health Organization. Health is here defined as "a state of complete physical, mental and social well-being and not merely the absence of diseases or infirmity".
As the more serious health hazards are absent, it is obvious that the measures to be taken for odour abatement will depend, among other things, upon the extent to which a specific country or a specific industry can afford such measures. Notwithstanding such considerations, it must always be of importance to try to evaluate as correctly as possible the extent to which the exposed population is affected by the odours. Unfortunately, no very objective method exists; reliance must be placed on various types of interview and survey methods. However, advances in sociology during recent years have made it possible to obtain fairly good estimates of the reactions of a population to such stimuli as odours and noise. Interview surveys around two Swedish mills have shown that in the neighbourhood of these mills about 30 to 40 per cent. of the respondents consider themselves annoyed by the odours and about 10 to 20 per cent. of them express severe annoyance (Figs 5 and 6). By comparing the relationship between the exposure (odour units or concentration of sulfurous substances) and the response (annoyance reactions) near several mills, it might be possible in the future to obtain guides for evaluating, in greater detail, the dose-response curves and thus make it easier for industries and public health officials to decide the proper abatement measures.

The common procedure of relying on spontaneous actions (e.g. petitions to health authorities) has, according to Swedish experience, a low validity for quantitative estimations. For example, there were 1200 persons near one particular mill who signed a petition for "measures to be taken to eliminate the nuisance due to the malodorous gases, failing which, that the operations at the factory shall be discontinued until further notice". An interview study, covering among others a sample from the petitioners, showed that 47 per cent. of those who had signed the petition had not been annoyed at all and that only 31 per cent. of them had reported major annoyance. In this specific case, the petition mainly expressed the view of a few very influential people.
REFERENCES

1. Felicetta, V. F., Peniston, Q. P. & McCarthy, J. L. (1953) TAPPI, 36, 425
12. Young, F. A. et al. (to be published in Perception and Psychophysics)
15. Cederlöf, R. et al. (1964) Nord. hyg. T., 45, 39
### Table 1

<table>
<thead>
<tr>
<th>Substance</th>
<th>Odor threshold</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>mg/l</td>
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</tr>
<tr>
<td>Hydrogen sulphide</td>
<td>$11 \times 10^{-4}$</td>
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</tr>
<tr>
<td></td>
<td>$12-30 \times 10^{-6}$</td>
<td>3</td>
</tr>
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<td></td>
<td>$12 \times 10^{-6}$</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>(1,1$ \times 10^{-6}$)</td>
<td>12</td>
</tr>
<tr>
<td>Methylmercaptan</td>
<td>$11 \times 10^{-4}$</td>
<td>10</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>Dimethylsulphide</td>
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<td>Dimethyldisulphide</td>
<td>38</td>
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### Table 2

<table>
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<th>Plant</th>
<th>Source</th>
<th>Dilution factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Gas from the recovery furnace</td>
<td>$10^{3.8}$</td>
</tr>
<tr>
<td>A</td>
<td>Gas from the Bergström tower</td>
<td>$10^{5.2}$</td>
</tr>
<tr>
<td>A</td>
<td>Gas from the filter wash</td>
<td>$10^{5.4}$</td>
</tr>
<tr>
<td>B</td>
<td>Gas from the chlorine scrubber</td>
<td>$10^{5.7}$</td>
</tr>
<tr>
<td>A</td>
<td>Uncondensed gases from evaporation</td>
<td>$10^{7.4}$</td>
</tr>
<tr>
<td>A</td>
<td>Uncondensed gases from the digester house</td>
<td>$10^{7.7}$</td>
</tr>
<tr>
<td>B</td>
<td>Gas emerging from the oxidation tower</td>
<td>$10^{7.8}$</td>
</tr>
<tr>
<td>B</td>
<td>Gas entering the oxidation tower</td>
<td>$10^{8.9}$</td>
</tr>
</tbody>
</table>
Odor threshold

• Gases dissimilar, air smells

WHO 80835

No smell in either

Gases dissimilar, test-gas smells

---

Fig. 1
Fig. 2  RESPONSE CATEGORIES
1. Gases dissimilar, air smells
2. No smell in either
3. Gases dissimilar, test-gas smells
Fig. 3  ESTIMATED ODOR FREQUENCY

Hours/month
**Fig. 4** CORRELATION BETWEEN H$_2$S AND ODOR THRESHOLD
Fig. 5  RELATIVE NUMBER OF RESPONDENTS "SEVERELY ANNOYED" (PER CENT.)
Fig. 6  RELATIVE NUMBER OF RESPONDENTS "SEVERELY ANNOYED" (PER CENT.)
Air Pollution Surveys and Methods of Measurement
Much attention is paid in the USSR to methodological problems in air pollution surveys. In 1962 the Ministry of Health approved methodological instructions\(^1\) for air pollution surveys prepared by the A. N. Sysin Institute of General and Municipal Hygiene of the USSR Academy of Medical Sciences. The instructions are now being revised and a new edition will be published shortly.

The assessment of the degree of air pollution in the USSR is based on the determination of the weight concentration of the contaminant (mg/m\(^3\)). Other indices (for instance, the number of particles per unit volume; the weight of the contaminant retained by a screen or filter, etc.) are not used except for special purposes. The concentration of air pollutants fluctuates greatly with time and is influenced by many factors; some of these factors affect the 'true' concentration, others the 'analytical' concentration (for example, the concentration as determined by analysis depends on sampling time and/or the number of samples used for estimating the average concentration). As the sampling time and the amount of material analysed are increased, the variability becomes smaller and the observed maximum values are lower. Thus, to obtain comparable data, it is necessary to use standard sampling and analytical methods. The sampling time and the frequency of sampling must also be fixed. All these points are covered in the above-mentioned methodological instructions.

It is an accepted practice in the USSR to base the estimation of the degree of air pollution on two concentrations, the 24-hour average concentration and "the maximum concentration at any time". The 24-hour or daily average concentration is determined either by continuous sampling or by intermittent sampling every two to four hours. When the sampling is intermittent the 24-hour average concentration is either calculated from six to twelve separate analyses or the air is aspirated, at chosen intervals of time and for a defined period, through the same absorber. Daily average concentrations are, of course, levelled out and give little information about peak concentrations occurring during shorter intervals of time.

For substances which have an offensive odour or which irritate the upper respiratory tract or the mucus membranes of the eye, the single maximum concentration is also estimated. The single maximum concentrations, or "the maximum concentrations at any time" are determined by short-term sampling (20 minutes) in the plume of the pollution source when the plant is operating at full capacity and when the meteorological conditions are unfavourable. If there are several sources of air pollution - which is often the case in modern industrial areas - the 'single' concentrations are determined by systematic daily sampling over a long period of time (up to one year). Samples are taken once or twice daily.

Two situations are typical with regard to industrial air pollution sources: (a) there are several air pollution sources within the inhabited area, and (b) there is only one main source of industrial air pollution. Consequently there are two possible ways of organizing an air pollution survey. In towns with multiple industrial air pollution sources where diffuse pollution is prevalent, the most adequate method is to set up a network of stationary sampling points. Correct distribution of sampling points is of utmost importance for a successful air pollution survey. The choice of sampling points should be preceded by:

(a) study of natural geographic factors (relief of the terrain, presence of surface water bodies, etc.);

(b) study of the city lay-out (town planning) and the plan for its development; distribution of industrial plants, residential areas, main highways; distribution of green areas, empty areas etc.,;
(c) study of 'wind roses' and other meteorological conditions;
(d) study of the technological processes of various industrial plants located in the area and of the physicochemical and toxicological properties of gaseous effluents.

Particular attention should be paid to a detailed description of air pollution sources (rate of emission, total volume of gases emitted, height of stacks, number of emission points and their diameters, temperature of effluents and rate of atmospheric diffusion). A list should also be made of the existing effluent purification installations and of their operational efficiency.

A choice of stationary sampling points is then made in such a way as to facilitate the collection of data on air pollution in the centre of the town, at its periphery and in different parts of the area, and to enable the estimation of the extent of air pollution by industrial and other sources to be made. Since the stationary sampling points are set up to assess the degree of diffuse air pollution, they should be situated at least 500 m away from stacks and placed on well 'winded', open plots of land; these sites should be covered either by grass or asphalt.

The number of stationary points will depend on the size of the town and local conditions. The usual size of the network in a town is about eight to ten sampling stations.

Samples are collected for determination of dust, sulfur dioxide, carbon monoxide and formaldehyde. The frequency of sampling for these four contaminants varies from sampling point to sampling point. The largest number of samples for dust and SO$_2$ determination should be collected in smoky areas, in residential districts and in the vicinity of railway stations. Since carbon monoxide and formaldehyde are characteristic ingredients of automobile exhaust gases the frequency of sampling for these contaminants should be highest near highways. In addition to these four contaminants, other samples are collected for determination of air pollutants characteristic of local industry. Samples are collected: in the morning between 8 a.m. and 10 a.m., when the atmospheric convection and turbulence are low; and in the evening between 6 p.m. and 8 p.m., when there is a sharp drop in air turbulence. The sampling time should be changed if the period of maximum discharge of effluents occurs at other hours of the day. Besides the 'single' (short-term) samples, it is advisable to take 24-hour average samples about 10 to 15 times per season. The following meteorological measurements are carried out regularly at all stationary sampling points: wind velocity, temperature, humidity and barometric pressure. The sampling report should also contain a qualitative description of weather conditions (cloudy, foggy, rainy); the presence of soil dust should be pointed out and subjective sensations of the observer recorded (offensive odour, irritation of the eyes or of the upper respiratory tract, etc.). Meteorological data collected at the sampling point should always be compared with the data collected by the local meteorological station. The analysis of air pollution data collected at the stationary points facilitates the estimation of pollution levels and understanding of the dynamics of air pollution in different regions of the investigated air basin. Daily variations in the concentration of each contaminant are examined separately, and the average monthly and maximum monthly concentrations recorded. The average monthly concentration is compared with the 24-hour average maximum permissible concentration, and the maximum monthly with "the maximum permissible concentration at any time". The yearly dynamics of air pollution of an air basin are assessed only on the basis of average concentrations, obtained under similar meteorological conditions.

Air pollution surveys in inhabited areas with one basic industrial air pollution source are carried out either by systematic measurements at stationary sampling points or by periodic studies of zonal distribution of industrial effluents.

The organization of systematic air pollution surveys is the same as in the case of multiple pollution sources, the only difference being that the number of stationary sampling points is reduced to two or three stations. One of these stations should be situated in the most polluted part, another in the least polluted part of the area.
There are some special features of the organization of zonal distribution studies which should be briefly described.

If the objective of such a study is to estimate the maximum concentrations and the range of air pollution from a given source, the sampling points should be distributed in the direction of the wind. The samples are taken at different distances from the source (for example 100 m, 500 m, 1000 m, 2000 m, 3000 m, etc., depending on the intensity of emission, the height of stacks, and the local topography). The sampling frequency should be the highest in the zone of maximum 'smokiness', that is about 10 to 40 stack heights from the source. It must also be remembered that in some cases air pollution diffuses to considerable distances and, therefore, air samples should be taken not only under the 'plume' but also much further away.

In order to assess the extent or degree of 'un-organized' effluent discharge, the air sampling should also be done in the immediate vicinity of the plant, starting at the limit of the sanitary protective zone.

It is desirable to take as many air samples as possible simultaneously at several different points under the plume. If this is not technically feasible, the space distribution of sampling points should be changed frequently in order to obtain enough information on air pollution levels at different distances from the source, under different meteorological conditions. Not less than 25 samples should be taken at one distance under analogous meteorological conditions. In order to obtain information about seasonal variations in the degree of air pollution, sampling surveys should be organized in seasonal cycles, from two to three weeks in each season. The samples should be collected at different times of the day. It is also convenient to classify the samples taken according to the prevalent degree of cloudiness and the wind speed.

Samples for the determination of specific pollutants should be collected once or twice daily under conditions of maximum air pollution (full capacity operation of the plant, unfavourable meteorological conditions). In order to avoid the underestimation of pollutant concentrations, the wind direction should be strictly followed. The sampling time under the plume should be 20 minutes in order to obtain data comparable with the "maximum permissible concentration at any time".

Apart from ambient air sampling, periodical collection of air samples within houses is recommended; the effects of industrial air pollution on vegetation should also be systematically recorded (premature fading or scorching of leaves, damaging of forests, reduction in crops, etc.). Such observations should be documented by drawings or photographs.

Zonal distribution studies enable us: to assess whether the maximum permissible air pollution levels are exceeded, and how often; to assess whether the sanitary protective zones are wide enough and effective; to estimate the effect of the plant operation regime on air pollution levels and to assess the efficiency of effluent purification installations; and finally to estimate the possible effects of air pollution on the health and living conditions of the population.

REFERENCE

There are two main difficulties in the determination of pollutants in ambient air. Their concentrations are small and the analysis has to be made in the presence of many other chemically different and often interfering substances. The concentrations of atmospheric pollutants may vary from a fraction of a $\mu$g/m$^3$ to several mg/m$^3$, and accordingly various analytical methods of differing sensitivity have been recommended: gravimetric, volumetric, optical (colorimetry, spectrophotometry, spectrofluorimetry), electrochemical (polarography, potentiometry, conductometry), chromatographic and others.

Sampling methods will not be discussed here but it should be pointed out that the size of sample should always be adapted to the sensitivity of the method used.

In most cases the sensitivity of gravimetric methods (0.1 mg) is not sufficient and they are recommended only in some special cases, for instance for estimating the weight concentration of dust or suspended matter. The suspended particles are collected by filtration of air through a special hydrophobic synthetic filter of high efficiency (95 to 99 per cent.) and low resistance, and the mass of the collected matter is determined by weighing the filter before and after filtration. The size of the sample should be of the order of 1.5 to 3.0 m$^3$.

Volumetric methods (acidimetry, alkalimetry, iodimetry, etc.) are also rarely used for the same reason (sensitivity of the order of 0.1 mg/m$^3$), and are gradually being replaced by colorimetric and spectrophotometric methods.

Colorimetry and absorption spectrophotometry are widely used in analytical chemistry of air pollutants. The sensitivity of these methods is fairly high and ranges from about 0.005 to 0.1 $\mu$g/m$^3$. Analytical procedures are usually simple and a photo-electric spectrophotometer is available in almost any larger sanitary-epidemiological laboratory in the USSR. The principle of absorption spectrophotometry as applied to analysis of air pollutants is very simple: the air sample is aspirated through a suitable liquid absorber which retains the pollutant; the absorbance of the solution is measured either directly or after a suitable chemical reaction; the position of the absorption maximum is characteristic for a given substance and may be used for its identification (Fig. 1); the height of the maximum is proportional to the concentration of the substance. Several examples of absorption spectrophotometric methods used in the USSR for determination of air pollutants will be briefly described.

In sulfuric acid medium, formaldehyde reacts with 1,8-dihydroxynaphthalene-3, 6-disulfonic acid producing a reddish-violet colour the intensity of which is proportional to the amount of formaldehyde. The sensitivity of this method for determination of formaldehyde in ambient air is of the order of 0.2 $\mu$g/ml of absorbing solution.

Nitrogen dioxide (NO$_2$) absorbed from air and transformed into a diazo-compound (by interaction in acid medium with sulfanilic acid) reacts with N-(1-naphthyl)-ethylene-diamine producing an azo-dye of purple colour. The sensitivity of this method is 0.02 $\mu$g/ml of solution.

A spectrophotometric method is also used for determination of volatile mineral acids (HCl, HNO$_3$) in ambient air. The air sample is aspirated through distilled water and the absorbance is measured at 530 nm after adding methyl-red indicator. A sample of five to eight litres is sufficient to determine a concentration of 0.1 mg of volatile mineral acids per 1 m$^3$ of air.

Carbon dioxide in air is also measured by a spectrophotometric method. 100 ml of air is aspirated into a syringe containing the absorbing solution (a mixture of one part of
0.125 per cent, aqueous solution of bromothymol blue and 50 parts of an 0.025 per cent, solution of NaHCO₃). The concentration of carbon dioxide is estimated from the absorbance of the solution. One test takes about five minutes.

Another example of the application of spectrophotometry in air pollution analysis is the measurement of metal aerosols and vapours (lead, mercury, copper, etc.) by monocolour or mixed colour dithizone methods.

Ultra-violet absorption spectrophotometry has also been applied successfully in several cases. One example of this method is the determination of ozone in ambient air. Air is aspirated through a weakly acid solution of dihydro-acridine in ethanol (pH=5.8). If oxidizing substances are present in air dihydro-acridine will be oxidized into acridine which has an absorption band in the ultra-violet region. If the absorbance is measured at 249.5 mÅ an amount of 0.004 µg of O₃ per ml of solution can be determined. With an air sample of 10 litres, a concentration 0.0004 mg/m³ of ozone in air is measurable. The interference of other oxidants is eliminated in the following way: one sample of air is aspirated through a U-tube filled with pumice and concentrated sulfuric acid followed by the liquid absorber; the other sample is first passed through the sulfuric acid-pumice mixture, then through another U-tube filled with manganese dioxide and finally through the liquid absorber containing ethanol solution of dihydro-acridine (Fig. 2). Manganese dioxide eliminates ozone by catalytic decomposition. The difference in absorbance of the two ethanol solutions is a measure of the amount of ozone present in air. This method has been successfully applied in measuring ozone in Moscow air. Some of the results are shown in Table 1.

### TABLE 1. OZONE CONTENT IN AMBIENT AIR OF A 'CLEAN' MOSCOW RAYON, MEASURED AT THE FOURTH-FLOOR LEVEL BETWEEN 12 A.M. AND 3 P.M.

<table>
<thead>
<tr>
<th>Date</th>
<th>Absorbance</th>
<th>Concentration of ozone (mg/m³)</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All oxidants</td>
<td>Ozone only</td>
<td></td>
</tr>
<tr>
<td>7.10.66</td>
<td>0.159</td>
<td>0.051</td>
<td>0.014</td>
</tr>
<tr>
<td>8.10.65</td>
<td>0.080</td>
<td>0.030</td>
<td>0.008</td>
</tr>
<tr>
<td>11.10.65</td>
<td>0.121</td>
<td>0.084</td>
<td>0.025</td>
</tr>
<tr>
<td>12.10.65</td>
<td>0.025</td>
<td>0.082</td>
<td>0.024</td>
</tr>
<tr>
<td>13.10.65</td>
<td>0.070</td>
<td>0.038</td>
<td>0.011</td>
</tr>
<tr>
<td>14.10.65</td>
<td>0.155</td>
<td>0.038</td>
<td>0.011</td>
</tr>
<tr>
<td>15.10.65</td>
<td>0.233</td>
<td>0.082</td>
<td>0.024</td>
</tr>
<tr>
<td>16.10.65</td>
<td>0.157</td>
<td>0.084</td>
<td>0.025</td>
</tr>
<tr>
<td>20.10.65</td>
<td>0.142</td>
<td>0.060</td>
<td>0.016</td>
</tr>
<tr>
<td>25.10.65</td>
<td>0.106</td>
<td>0.063</td>
<td>0.017</td>
</tr>
<tr>
<td>27.10.65</td>
<td>0.000</td>
<td>0.035</td>
<td>0.010</td>
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<td>1.11.65</td>
<td>0.030</td>
<td>0.045</td>
<td>0.005</td>
</tr>
<tr>
<td>2.11.65</td>
<td>0.005</td>
<td>0.020</td>
<td>0.005</td>
</tr>
<tr>
<td>3.11.65</td>
<td>0.000</td>
<td>0.020</td>
<td>0.005</td>
</tr>
</tbody>
</table>

The bathochromic effect of pH on aqueous solutions of phenols (phenol, o-, m-, and p-cresol) is the base for a method for determination of phenols in ambient air. The maximum absorption of UV light of neutral aqueous solution of phenols occurs at 235 mÅ. If pH is increased to 13.0 the absorption maximum shifts to about 270 mÅ and its height is reduced. By measuring the absorbance at 235 mÅ twice, at pH=7.0 and at pH=13.0, the interfering influence of substances which absorb at about the same wavelength (235 mÅ) but do not show the bathochromatic effect can be eliminated. The sensitivity of the method is 0.015 µg/ml of solution (1 cm quartz cells).
The fine structure of fluorescence spectra is used for determination of polycyclic hydrocarbons in ambient air, in particular for estimating the concentration of 3,4-benzpyrene. The method is based on the so-called Spol'skij's effect: if solutions of 3,4-benzpyrene or other polycyclic hydrocarbons in some paraffins (e.g. n-hexane, n-heptane, n-octane) are cooled down to the temperature of boiling nitrogen (-196°C) their fluorescence spectra change. The comparatively wide band spectra break down into a system of very narrow bands, resembling atomic spectra, and it is possible to measure simultaneously the relative intensity of fluorescence of several polycyclic hydrocarbons even if their fluorescence spectra overlap under ordinary conditions. The determination of 3,4-benzpyrene in airborne dust is carried out in four stages: (a) benzene extraction of the dust sample; (b) chromatographic fractionation of the extract (column or thin layer chromatography); (c) identification of 3,4-benzpyrene by means of its low temperature fluorescence spectrum; and (d) estimation of the intensity of fluorescence at 403 nm. The reported sensitivity of the method is 0.001 µg/ml of solution. A sample of 300 m³ of air is required to determine 0.001 to 0.1 µg/m³ 3,4-benzpyrene.

Another optical method widely used in the analysis of air contaminants is nephelometry. An example of the application of this method is the determination of SO₂ in ambient air. Air is aspirated through aqueous solution of potassium chlorate and the absorbed SO₂ is thus oxidized to sulfuric acid. On addition of a barium chloride solution a barium sulfate sol is produced; its concentration is determined nephelometrically. The reported sensitivity amounts to 1 µg per 1 ml of solution.

The presence of aliphatic hydrocarbons in air is quantitatively determined by gas chromatography. A sensitivity of 0.1 µg/m³ may be attained if an accumulation procedure precedes chromatographic analysis.

If the presence of several metals in air has to be measured simultaneously, polarography is the method of choice. A sensitivity of 0.1 to 0.01 µg/ml may be attained.

If the variation of air pollution with time has to be studied, it is very useful to apply automatic sampling and monitoring instruments based on chemical, electrochemical or optical principles.
REFERENCES

1. Gil'denskjold, R. S. & Minakov, A. A. (1962) Gig. i Sanit., No. 1, p. 40
2. Alekseeva, M. V. & Elfimova, E. V. (1958) Gig. i Sanit., No. 8, p. 71
3. Alekseeva, M. V. et al. (1954) Determination of noxious substances in air of industrial premises (in Russian), Moscow, Goshimizdat, p. 360 (This method has been modified by V. I. Melehina)
4. Šerševskaja, I. S. & Voroncova, E. (1941) Gig. i Zdorovje, No. 3, p. 49
5. Manita, M. D. & Melehina, V. P. (1964) Gig. i Sanit., No. 3, p. 53
6. Manita, M. D., Eliseeva, O. V. & Diško, T. V. (1964) Gig. i sanit., No. 12, p. 57
7. Manita, M. D., Rumanceva, O. V. & Eglite, M. E. (1967) Gig. i Sanit., No. 5, p. 56
8. Manita, M. D. (1966) Gig. i Sanit., No. 8, p. 60
10. Kosina, A. Ja. (1964) Materialy XIII Vsesojuznogo soveščanija po ljuminiscencii, p. 113
16. Buhovskaja, M. S. & Poletaev, I. (1952) Gig. i Sanit., No. 12, p. 47

Bibliographical note: Most of the USSR standard and recommended methods for determination of ambient air pollutants may be found in the following manuals:

Alekseeva, M. V. (1963) Determination of Atmospheric pollutants, Moscow, Medgiz (in Russian)

Ministry of Health of the USSR (1963) Methodological instructions for ambient air pollution investigations, Moscow, Medgiz (in Russian)

Gol'dberg, M. S., ed. (1966) Methods for determination of atmospheric pollutants (in Russian), Moscow, Academy of Medical Sciences of the USSR (Draft)


Korenman, M. N. (1967) Analytical chemistry of small concentrations, Moscow, Himia (in Russian)

Fig. 1  Ultraviolet spectra of styrene (C₆H₅CH=CH₂) and crotonaldehyde (CH₃CH=CHCHO)

Fig. 2  Air sampling assembly for determination of ozone in ambient air

1 - sulfuric acid - pumice mixture
2 - manganese dioxide
3 - ethanol solution of dihydro-acridine
Fig. 3  Absorption curves of aqueous solutions
phenol solutions (5 ug/ml)

1 - neutral solution, pH = 7.0
2 - alkaline solution, pH = 13.0
Effects of Air Pollution on Health
CHRONIC BRONCHITIS AND AIR POLLUTION

by

P. J. Lawther

In order to appreciate the complex problems involved in defining the relationship between chronic bronchitis and pollution of the ambient air, one must first look separately at the disease and the polluted environment.

Air pollution is complicated, chemically and physically. Its nature has been described in detail elsewhere and it might suffice here to say that it arises most commonly in Europe from the combustion, complete and incomplete, of coal and oil. When these fuels are burned efficiently, ideally, carbon dioxide and water are the only products which could pollute the atmosphere. There are, in addition, varying quantities of oxides of nitrogen derived from the fixation of atmospheric nitrogen, the amounts depending on conditions (notably temperature and pressure) of combustion.

In practice, however, fuels are frequently contaminated by compounds of sulfur which, when burnt, give rise to sulfur dioxide and smaller quantities of sulfuric acid.

Often, as a result of burning fuel in inappropriate or maladjusted appliances, combustion is incomplete and results in the production, commonly, of carbon monoxide and smoke. In certain countries, notably Great Britain, aerosols of tar are produced by the virtual distillation of raw coal on the open hearth of fireplaces used for domestic heating.

The result of these various processes is the production of a complex miasma of particles of carbon, tar and electrolytes floating in air polluted by sulfur dioxide, oxides of nitrogen, hydrocarbons and carbon dioxide, carbon monoxide and many other compounds. After these pollutants have been emitted, further reactions, such as oxidation of SO2 to sulfuric acid, or photochemical reactions of the complex type which occur over Los Angeles, may take place with the production of secondary pollutants.

Weather and climate are of great importance. Obviously if the climate is such that strong sunlight and chronically stable air rarely occurs, then we need not fear the production of Los Angeles type photochemically produced secondary pollution. If, on the other hand, temperature inversions in valleys in temperate coal-burning communities are frequent then we must fear the London/Meuse Valley type smoke fogs; and, in between, there will usually be 'chronic' pollution, too small in amount to give rise to dramatic increases in morbidity or mortality. It is obvious that the 'acute' and 'chronic' varieties of air pollution will have different roles to play in respect of the exacerbation and genesis of respiratory disease.

Chronic bronchitis is difficult to define: in its full-blown form, especially when it has progressed to give pathologically recognizable emphysema, there is little problem in diagnosis. There is, however, great danger in assuming that it is one disease with one clinical picture and one prognosis. It may start as unresolved pertussis in childhood; it may be associated with asthma or bronchiectasis; it may or may not progress to emphysema, or emphysema may be present with little history of preceding chronic bronchitis. For this reason, if for no other, there is everything to be said for research workers directing their studies to symptom complexes rather than to doctors' diagnoses,
Presented in its simplest clinico-pathological terms chronic bronchitis may be regarded as having two phases before passing into irreversible emphysema (if indeed it does). Simple chronic bronchitis consists of hypertrophy of the mucus secreting elements in the bronchial mucosa leading to the hypersecretion of mucus and, clinically, to chronic cough in order to expel the mucoid sputum. Airway obstruction will be proportional to the degree of mucous hypertrophy upon which will be added that produced by bronchoconstriction due to irritation or hypertoxicity from other causes.

There is abundant evidence that the smoking of cigarettes is of great importance in the production of this picture and it would seem that if the irritant be removed, the pathological picture regresses and the clinical state abates. Most commonly, alas, infection supervenes, and the establishment of foci of bacterial growth leads to the expectoration of purulent sputum and to constitutional illness in response to the systemic infection. Should this infection (which, commonly, is with H. influenzae and S. pneumoniae) not be eradicated promptly, then irreparable damage will be done to the lung parenchyma and this, together with the airway obstruction referred to above, will eventually lead to emphysema with its dread sequelae of anoxia, CO₂ retention and cor pulmonale.

There is evidence that an urban factor plays an important part in this stage of the disease in which smoking is more an exacerbating than etiological factor. It is likely that air pollution plays a part here.

There is thereafter no doubt that in patients with the established disease air pollution, in higher concentration than that observed day by day, can play an important role in producing worsening of the disease, sometimes fatal, by irritation of the respiratory tract. Evidence for these opinions was presented and discussed.
POLLUTION OF THE AMBIENT AIR BY CARCINOGENIC SUBSTANCES AND CANCER OF THE LUNG

by

L. M. Sabad

Many facts indicate that inhalation of air polluted by carcinogenic substances plays a decisive role in the etiology of lung cancer. The idea that some substances may be carcinogenic agents is based on studies of occupational cancer; but occupational cancer represents only a small fraction of the total number of cancer cases, and the elimination of occupational cancer cannot contribute essentially to the solution of the problem as a whole. There are, however, instances when an occupational hazard becomes a public health hazard, affecting large groups of people. This is clearly evident in the case of contamination of ambient air by carcinogenic hydrocarbons.

If the high degree of atmospheric pollution by smoke observed in some large industrial towns and in whole regions is kept in mind, it is not surprising that in air samples taken in such areas carcinogenic hydrocarbons could be found, in particular such potent carcinogenic substances as 3,4-benzpyrene.

The first systematic investigations about the contamination of urban air by carcinogenic hydrocarbons were published in the USSR, Great Britain and the United States of America some 15 years ago.

The pollution of air by carcinogenic substances can be reduced as shown by the following example: in Makeevka town (Donbass) there was an old coke plant causing considerable air pollution in the neighbouring settlement; following the installation of after-burning devices the discharge of noxious effluents diminished, and the level of 3,4-benzpyrene in air samples was reduced a thousand times. Smoke from heating systems and industrial establishments is not the only source of carcinogenic substances in the ambient air. Exhaust gases from automobiles also contain carcinogenic hydrocarbons, in particular 3,4-benzpyrene. By controlling fuel quality and particularly by improving combustion, it is possible to reduce the ambient air pollution from this source as well. Some data on the levels of 3,4-benzpyrene in the USSR urban areas are given in Table 1.

Smoking is another important etiological factor in lung cancer, as has been shown by extensive clinical-statistical studies, but in order to give a final assessment of the hypothesis that carcinogenic substances play an etiological role in cancer of the lung, it was necessary to provide direct experimental proof. Using fluorescence spectroscopy, it was shown that tobacco smoke contains 3,4-benzpyrene (1.6 μg per 100 smoked cigarettes and 1.1 μg per 100 'papirosa'). Experiments performed on animals also showed that undoubted tumours of the skin and subcutaneous tissue can be produced by tobacco resins, although only in a small percentage of experimental animals. However, for a long time all experiments designed to prove that carcinogenic substances can produce lung cancer failed.1-3

By carefully analysing previous unsuccessful experiments the author and his collaborators reached the conclusion that the failure to produce experimental cancer of the lung was due to insufficient deposition of carcinogenic substances in the lung tissue. Consequently, it was decided to increase the dose of the carcinogenic agent to the maximum possible level, and at the same time to create such conditions as to retain as long as possible a high content of the carcinogenic substances in the lung tissue. For this purpose, carcinogenic agents (7,12-dimethylbenz(a)anthracene - DMBA and 3,4-benzpyrene-BP) were repeatedly applied to rats by means of intra-tracheal intubation of a suspension of the carcinogenic substance in the colloidal "infuzin" (a solution of non-anaphylactogenic casein) containing powdered Indian ink.8

8 'papirosa' is a cigarette with a long paper holder, produced in the USSR.
TABLE 1

3,4-benzpyrene concentrations in ambient air in some urban areas of the USSR (in μg/m³)

<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leningrad</td>
<td>43.3</td>
<td>4.43</td>
</tr>
<tr>
<td>Sverdlovsk</td>
<td>5.5</td>
<td>1.74</td>
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<td>Tbilisi</td>
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<td>Irkutsk</td>
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<tr>
<td>Kalinin</td>
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<td>Riga</td>
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<td>0.28</td>
</tr>
<tr>
<td>Angarsk (district heating, oil)</td>
<td>0.16</td>
<td>0.12</td>
</tr>
<tr>
<td>Angarsk (district heating, new residential areas)</td>
<td>0.11</td>
<td>0.11</td>
</tr>
</tbody>
</table>

The purpose of casein and Indian ink (which are good adsorbents) was to establish a depot of carcinogenic hydrocarbons in the lung tissue. DMBA was applied in amounts of 2 to 10 mg, one, three or five times; BP in amounts of 5 mg per intubation, the total dose being 25 to 35 mg. Under these conditions within approximately 75 days, all experimental animals developed specific changes in the bronchial epithelium. In most cases processes of metaplasia developed from the outset, and owing to this adenomatous foci turned into foci of planocellular keratotic epithelium. It should be pointed out that the initial proliferation of epithelium of the bronchi appeared at points of deposition of the carcinogenic substance; this was evident from the clearly noticeable deposits of Indian ink. Such adenomas can develop into larger tumours covering a whole lobe. They possess infiltrative growth capacity and yield metastases, i.e. they become true adenocarcinomas. Thus, in a number of cases it was possible to observe obvious planocellular cancer of the lung with varying degrees of keratosis. Sometimes in such a tumour there was a well-developed fibrous stroma, and the tumour looked like a scirrhus.

These results should be contrasted with data, also on rats, obtained by L. A. Gricjute, who repeatedly introduced by tracheotomy the same carcinogenic agent (DMBA) in physiological solution but, in spite of the appearance of pre-cancerous changes, never observed cancer of the lung. The essential difference in the methods used by Pylev and by Gricjute was that Pylev applied adsorbents while Gricjute did not. Pylev produced experimental bronchogenic cancer of the lung by DMBA in 30 per cent., and by BP in up to 70 per cent. of cases.

It should be pointed out that the present author and his collaborators also succeeded in producing cancer of the lung using the same substance, BP, which is the most usual carcinogenic substance in the polluted air of urban areas, in tobacco smoke, in the exhausts of motor vehicles etc.

This experimental 'model' of cancer of the lung can be further used for various practical purposes, in particular for assessment of the significance of certain dose levels of carcinogenic substances. For example, in the first experimental series it was found that intratracheal application of 6 mg of DMBA produces cancer of the lung in 30 per cent. of rats while 2 mg was effective in 17 per cent. of animals only (see Table 2).
## TABLE 2

Production of lung cancer in rats by DMBA

<table>
<thead>
<tr>
<th>Series</th>
<th>Amount of DMBA administered</th>
<th>Total dose (mg)</th>
<th>Number of animals dying after five months from the beginning of experiment</th>
<th>Number of rats with tumours of lungs</th>
<th>Metastases</th>
<th>Percentage of tumours observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>squamous carcinoma</td>
<td>adenocarcinoma</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Single injection of 2.5 mg</td>
<td>2.5</td>
<td>34</td>
<td>6</td>
<td>2</td>
<td>17.6</td>
</tr>
<tr>
<td>2</td>
<td>Three injections of 2 mg</td>
<td>6.0</td>
<td>56</td>
<td>20</td>
<td>1</td>
<td>37.5</td>
</tr>
<tr>
<td>3</td>
<td>Five injections of 2 mg</td>
<td>10.0</td>
<td>61</td>
<td>17</td>
<td>1</td>
<td>29.5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>151</td>
<td>43</td>
<td>2</td>
<td>29.8</td>
</tr>
</tbody>
</table>
It has been mentioned in the literature that carcinogenic hydrocarbons were almost entirely eliminated from the lung 24 hours after application, and that repeated administration did not lead to any accumulation of the substance in the tissue. The present author pointed out that particles of Indian ink and "infuzin" (colloidal solution of a protein) were adsorbents which retained the carcinogenic substance and therefore facilitated the production of the cancer. In order to prove this hypothesis, Sabad, Pylev and Kolesničenko designed a series of experiments to elucidate the dynamics of elimination of BP from the lung under different conditions (composition of the supporting solution, frequency of administration). Four experiments were performed involving 201 rats. In the first series of experiments, 5 mg of BP was administered intra-tracheally together with 0.5 mg of Indian ink in 0.2 ml of "infuzin"; in the second series the same amount of BP was administered in 0.2 ml of "infuzin" but there was no Indian ink; in the third series benzpyrene was introduced with 0.5 mg of Indian ink in 0.2 ml of physiological solution; in the last series 5 mg of BP was given in 0.2 ml of physiological solution. The intra-tracheal application was repeated three times, with an interval of one month between each successive administration. Three rats were examined 1, 3, 5, 7, 18 and 30 days after each application, and BP was extracted from their lungs. The results obtained after the first administration are shown in Table 3.

In the whole series of experiments, one regular feature was repeatedly observed: the elimination of BP from the lung was rapid and significant whenever BP had been introduced with the physiological solution. The reason for the lack of accumulation after repeated administration also became evident: 18 to 30 days following the administration, there was no BP left in the lung tissue if the carcinogenic hydrocarbon was introduced with the physiological solution only. A completely different picture was obtained when the results of the first series were examined. There was a marked increase in the amount of BP extracted from (and hence, deposited in) the lung tissue, with repeated administration (see Table 4).

The presence of Indian ink and "infuzin" caused a significantly longer retention of BP in the lung tissue and, consequently, an accumulation with repeated application. It appeared also that the rate of accumulation of BP gradually increased; the accumulation between the second and third administration was significantly higher than between the first and the second administration. When Indian ink and "infuzin" were injected separately no increase in retention, depending on the lapsed time or the number of administrations, was observed. It seemed, therefore, that the decisive factor in retention of BP in the lung tissue was the type, the combination and, probably, the amount of adsorbent administered.

The results of these experiments seem to prove the present author's hypothesis that the formation of a depot of a carcinogenic substance is an indispensable condition for experimental induction of lung cancer; such a depot can be established by repeated administration of the carcinogenic substance with some kind of adsorbent. Using this technique, experimental cancer of the lung can now be provoked by chemical carcinogenic agents in a significant fraction of cases. So far this has been possible only by introducing into the lungs insoluble radioactive material. In the few cases where cancer of the lung could be produced by chemical carcinogenic agents, this was made possible only by forming a depot of the carcinogenic substance in the lungs.

There is an increasing amount of evidence that the formation of a depot of carcinogenic material is an essential part of the mechanism by which chemical carcinogenic agents produce cancer of the lung. Data derived from a comparative study of carcinogenesis in the lungs of different animals supports the assumption that the extent, the localization and the type of neoplasms depend on those anatomical and physiological characteristics of the lung tissue (primarily of the bronchial tree) which facilitate the retention and formation of a depot of carcinogenic material, for example in the mucus secreting glands of the bronchi. A significant role can, perhaps, be attributed to the adsorption of carcinogenic substances on soot particles of different size which reach the lungs with inhaled air.
Table 3

The amount of carcinogenic substance (BP) (percentage of the amount introduced) remaining in the lungs of experimental animals (first application)

<table>
<thead>
<tr>
<th>Series</th>
<th>Composition of the mixture</th>
<th>Time in days</th>
<th>1</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>18</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3,4-benzpyrene</td>
<td>58.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Indian ink</td>
<td>53.3</td>
<td>23.3</td>
<td>18.00</td>
<td>7.67</td>
<td>3.00</td>
<td>0.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ &quot;infuzin&quot;</td>
<td>50.0</td>
<td>24.3</td>
<td>16.76</td>
<td>6.67</td>
<td>3.00</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S.E. = ± 2.41 S.E. = ± 0.76 S.E. = ± 0.66 S.E. = ± 0.5 S.E. = ± 0.057 S.E. = ± 0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3,4-benzpyrene</td>
<td>55.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ &quot;infuzin&quot;</td>
<td>54.00</td>
<td>22.00</td>
<td>13.00</td>
<td>4.33</td>
<td>1.00</td>
<td>0.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>59.67</td>
<td>-</td>
<td>10.67</td>
<td>6.33</td>
<td>0.97</td>
<td>0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S.E. = ± 1.1 S.E. = ± 1.7 S.E. = ± 0.8 S.E. = ± 0.9 S.E. = ± 0.17 S.E. = ± 0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3,4-benzpyrene</td>
<td>48.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ Indian ink</td>
<td>50.67</td>
<td>22.67</td>
<td>14.00</td>
<td>8.00</td>
<td>2.83</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ physiological saline</td>
<td>-</td>
<td>22.97</td>
<td>12.67</td>
<td>6.80</td>
<td>2.73</td>
<td>0.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S.E. = ± 1.2 S.E. = ± 0.13 S.E. = ± 0.66 S.E. = ± 0.6 S.E. = ± 0.057 S.E. = ± 0.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3,4-benzpyrene</td>
<td>36.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ physiological saline</td>
<td>33.33</td>
<td>2.27</td>
<td>1.30</td>
<td>1.33</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>43.33</td>
<td>3.33</td>
<td>1.47</td>
<td>0.97</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S.E. = ± 2.94 S.E. = ± 0.18 S.E. ± 0.22 S.E. = ± 0.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 4

Mean relative amount of benzpyrene remaining in the lungs of experimental animals (expressed as percentage of the amount introduced)

<table>
<thead>
<tr>
<th>Time after administration in days</th>
<th>First series - administration of 3,4-benzpyrene in infuzin with Indian ink</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Third application (3rd month)</td>
</tr>
<tr>
<td>1</td>
<td>68.10</td>
</tr>
<tr>
<td>3</td>
<td>39.95</td>
</tr>
<tr>
<td>5</td>
<td>29.33</td>
</tr>
<tr>
<td>7</td>
<td>17.17</td>
</tr>
<tr>
<td>18</td>
<td>10.33</td>
</tr>
<tr>
<td>30</td>
<td>2.59</td>
</tr>
</tbody>
</table>

There is no doubt that the decisive factor in the etiology of lung cancer is the effect of carcinogenic substances, but at the same time it is reasonable to assume that chronic inflammation and its residual effects (impairment of the ciliary function of epithelium and its metaplasia; cicatricial changes impairing the peristalsis of the bronchi, etc.) are contributing factors because they disturb the physiological self-clearance of the lungs and thus facilitate the formation of depots of carcinogenic substances.

Air pollution surveys reveal that in a big modern industrial centre, along with other pollutants, several kilograms of benzpyrene may be discharged into the atmosphere per year. A fraction of this amount will eventually settle to the ground with natural fall-out (rain, snow) (Table 5). In view of this, it was thought interesting to search for the presence of benzpyrene in soil.

The first positive results were published by the author and his collaborators in 1959 when benzpyrene was detected in some soil samples taken in Leningrad. Since 1964 systematic studies of soil contamination by benzpyrene have been carried out in Moscow and its environs.

Soil samples were first dried and then in portions of 10 g extracted by benzene. Extracts were analysed (without preliminary chromatography) by a spectrofluorescence method developed by A. Ja. Hesina in the laboratory of the Institute for Experimental Cancer Research of the Academy of Medical Sciences of the USSR. The method is based on Špol'skij's effect, i.e. on the appearance of quasi-linear fluorescence spectra at low temperatures.

In the control samples, taken in recreation zones, no benzpyrene was detected. However, in Moscow itself the soil was found to be heavily contaminated, even in those regions that were not polluted by industry. In one district 268.5 µg of benzpyrene per kg of soil was found, and in another, even 346.5 µg. On the other hand, in a new residential area in Moscow there was only 104.5 µg of benzpyrene per kg of soil. Thus, the benzpyrene content in the soil of old districts in Moscow was found to be from two-and-a-half to three times higher than in the new districts. This is strong evidence of the stability of this substance and of the possibility of accumulation of BP in the soil. Even more interesting information was obtained in areas situated near major industrial air pollution sources discharging large amounts of carcinogenic hydrocarbons into the atmosphere. The benzpyrene content in soil samples taken near some oil refining plants,
amounted to approximately 200 000 µg per kg of soil. On the other hand, in soil samples taken in the vicinity of an asphalt plant operating in such a way that conditions for the formation of benzpyrene were not favourable (and the raw material - bitumen - did not contain this substance) about the same concentration of benzpyrene was found as in the old districts of Moscow, on average about 346.5 µg per kg of soil. In the industrial area of Birjulevo outside Moscow, where the main and, most probably, the only source of carcinogenic hydrocarbons is the railroad station, the BP concentration in the soil was on average about 80 µg. Approximately the same amount of benzpyrene was found in the soil of a farm outside Moscow, but near a highway with heavy traffic. Some of these results are summarized in Table 6.

### Table 5

Some data on 3,4-benzpyrene content in snow samples collected in Leningrad in 1954-55

<table>
<thead>
<tr>
<th>Sampling place</th>
<th>Amount of 3,4-benzpyrene in mg/m² per 180 days</th>
<th>Relative amount of 3,4-benzpyrene</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Kameni Ostrov</td>
<td>0.20</td>
<td>1</td>
</tr>
<tr>
<td>2. City centre</td>
<td>0.29</td>
<td>1.45</td>
</tr>
<tr>
<td>3. Viborg side, Arsenal street</td>
<td>7.80</td>
<td>39.00</td>
</tr>
<tr>
<td>4. Canal Rayon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td>2.60</td>
<td>13.00</td>
</tr>
<tr>
<td>(b)</td>
<td>0.37</td>
<td>1.80</td>
</tr>
<tr>
<td>5. Petrograd side</td>
<td>0.38</td>
<td>1.90</td>
</tr>
<tr>
<td>6. Control sample taken about 10 km out of town</td>
<td>0.008</td>
<td>0.004</td>
</tr>
</tbody>
</table>

*The amount of 3,4-benzpyrene in snow samples collected at Kameni Ostrov = 1.

### Table 6

BP soil pollution in different districts of Moscow

<table>
<thead>
<tr>
<th>Districts under investigation</th>
<th>Average content of BP (µg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Area of a plant with intensive BP emission</td>
<td>191 100</td>
</tr>
<tr>
<td>II. Old residential district</td>
<td>346.5</td>
</tr>
<tr>
<td>III. Another district of old Moscow</td>
<td>268.5</td>
</tr>
<tr>
<td>IV. New residential district</td>
<td>104.5</td>
</tr>
<tr>
<td>V. A settlement near Moscow</td>
<td>81.4</td>
</tr>
<tr>
<td>VI. A field near Moscow*</td>
<td>79.3</td>
</tr>
<tr>
<td>VII. Recreation area near the Klyasmosa water storage reservoir control zone</td>
<td>0</td>
</tr>
</tbody>
</table>

* Close to heavy traffic highway.
Further investigations revealed that the contamination of soil by benzpyrene extended over comparatively great distances of about 3 km from the air pollution source. The soil pollution level depended on the direction of the wind. These observations indicate that benzpyrene enters the soil from the air.

At the same time the contamination of vegetation growing on the polluted areas was also investigated. Spectrofluorescence analysis showed that all the examined samples of vegetation contained considerable quantities of benzpyrene (Table 7). Washing under running hot water for 30 minutes did not remove benzpyrene, indicating that part of the benzpyrene settling on the plants from the air can enter the pores of the leaves and find its way into the deeper layers of leaves and into the stem. There is also the possibility that benzpyrene is absorbed from the soil and not directly from the air. Preliminary experiments with plants growing on benzpyrene contaminated soil confirmed this possibility.

In collaboration with Mejsel' and his staff, the author studied in 1964 the absorption and metabolism of benzpyrene in various soil bacteria and yeasts. The absorption and accumulation of carcinogenic aromatic hydrocarbons in micro-organisms was detected by Mejsel' and, independently of him, by A. Graffi using luminescence microscopy. In 1964 Petrikevič found that the yeasts Endemycyes magnusia and Candida lipolytica have the ability to absorb benzpyrene added to the nutritive medium.

TABLE 7

<table>
<thead>
<tr>
<th>Sample</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without washing</td>
<td>5900</td>
<td>3300</td>
<td>3900</td>
<td>3100</td>
<td>2900</td>
<td>1900</td>
<td>1200</td>
<td>1100</td>
<td>1800</td>
<td>600</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>After washing</td>
<td>2100</td>
<td>-</td>
<td>2600</td>
<td>2900</td>
<td>400</td>
<td>800</td>
<td>700</td>
<td>700</td>
<td>1700</td>
<td>500</td>
<td>1000</td>
<td>800</td>
</tr>
</tbody>
</table>

In another study 17 strains of different soil bacteria could be isolated from a sample of soil taken on the territory of an oil refinery and containing about 100 000 µg/kg of benzpyrene. Selected strains of soil bacteria were cultivated on agar containing 10 µg of benzpyrene per ml of agar. The quantity of benzpyrene destroyed by the bacteria or degraded into derivatives not possessing typical luminescence, was determined by measuring the difference between the amount of hydrocarbon added to the nutritive medium and the amount which remained in the medium and the micro-organisms after two, three and four days. The results (Table 8) showed that in two cultures the amount of benzpyrene was practically unchanged while in the other two it almost completely disappeared.

It seems fairly well established that there are micro-organisms in the soil capable not only of accumulating benzpyrene but also of degrading it in considerable amounts. These types of bacteria apparently change 3,4-benzpyrene into less carcinogenic oxidation products or destroy it completely.
TABLE 8
Changes in the total content of BP in the medium and in the cells of soil micro-organisms during cultivation

<table>
<thead>
<tr>
<th>Culture</th>
<th>Period of cultivation</th>
<th>Amount of 3,4-benzpyrene</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Extracted (µg)</td>
<td>Transformed by bacteria (average %)</td>
<td>Extracted (µg)</td>
<td>Transformed by bacteria (average %)</td>
<td>Extracted (µg)</td>
</tr>
<tr>
<td></td>
<td>2 days</td>
<td>3 days</td>
<td>4 days</td>
<td>2 days</td>
<td>3 days</td>
<td>4 days</td>
</tr>
<tr>
<td>Test No.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>176</td>
<td>174</td>
<td>175</td>
<td>13</td>
<td>114</td>
<td>43</td>
</tr>
<tr>
<td>2/II</td>
<td>176</td>
<td>192</td>
<td>165</td>
<td>11</td>
<td>154</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>201</td>
<td>201</td>
<td>188</td>
<td>0</td>
<td>204</td>
<td>0</td>
</tr>
<tr>
<td>2/II</td>
<td>198</td>
<td>188</td>
<td>182</td>
<td>0</td>
<td>195</td>
<td>0</td>
</tr>
<tr>
<td>Control</td>
<td>208</td>
<td>201</td>
<td>198</td>
<td>0</td>
<td>203</td>
<td>210</td>
</tr>
</tbody>
</table>
Thus, it appears that there is a carcinogenic hydrocarbons cycle in the environment. Carcinogenic hydrocarbons suspended in air eventually settle to the soil and are either accumulated or washed out; they are either destroyed by soil bacteria, or migrate into vegetation and find their way into the food of domestic animals; in certain cases they may directly enter the food products consumed by man. The study of the hydrocarbons cycle in the environment presents paramount theoretical and practical interest; it may even reveal some facts that would be of interest in cancer prevention.

REFERENCES

9. Burykina, L. N. (1957) In: Toxicology of Radioactive substances, Moscow, Medgiz, pp. 102, 115 (in Russian)
METHODS OF STUDYING THE EFFECTS OF AMBIENT AIR POLLUTION ON THE POPULATION

by

M. S. Gol'dberg

Comprehensive investigations of air pollution in the USSR and of its effects on the population began in 1949. The main methodological trends of this work are summarized.

In the studies on the influence of ambient air pollution on living conditions and health of the population at least two different regions should be chosen; a residential district heavily polluted by industrial effluents, transport, etc. and a residential district with clean air - the control district. If a 'clean' district is not available it is permissible to choose a district where the pollution level is comparatively low - the relative control region. When the situation permits, three districts should be selected; a control district with no air pollution and two districts with different levels of pollution. In all other respects the districts under study should be as similar as possible, particularly with respect to the composition of the population and living conditions (income, housing, etc.) as well as to the quality and accessibility of the medical service.

There are two fundamental methods that can be applied in studies on the effects of air pollution on health: (a) the questionnaire method, and (b) the medical investigation of the state of health of different groups of population, based on clinical and laboratory methods of research.

Investigations of the effects of air pollution on the population should be preceded by a study of the type and level of pollution in the given residential district.

Medical investigations are carried out in one or two specially chosen areas of the polluted district as well as in a controlled unpollluted region. The nature and the extent of medical investigations should be decided in each case separately, and should be based on a careful study of the degree of pollution, of its sources and of the toxicological properties of air contaminants, and on the results of the questionnaire study; this pilot study will also determine the need for special staff and the character of laboratory studies required.

The investigation of the chosen groups of population should be carried out simultaneously (for example within one to two months), having in view possible time variations in the environment and the composition of population groups. Within the groups, those individuals have to be selected who have had no previous occupational exposure to toxic substances. A questionnaire study will be needed to carry out this selection correctly.

As already mentioned, the groups selected for detailed medical examination (about 300 to 400 individuals in the polluted area and about 150 to 200 individuals in the clean area) should be as similar as possible with regard to sex and age distribution, as well as to the length of stay in the polluted area.

The major part of such studies in the USSR was carried out not on adult individuals but on children (3rd or 4th class, elementary school). There are many advantages in choosing children as subjects for investigating the effects of air pollution, for instance a more intense absorption of toxic substances from inhaled air, a less developed detoxication capacity of young organisms and a more pronounced immunological reactivity. The absence of occupational exposure is another advantage.
Medical examinations should be carried out simultaneously by a group of physicians of various specialities, and all the necessary anthropometrical, clinical X-ray, haematological, biochemical, immunological and other research methods should be applied. The objectives of investigations could be:

(a) to detect in the organism the presence of toxic substances polluting the air;

(b) to detect changes in the organism specific for the effects of toxic substances found in the air;

(c) to detect non-specific protective or adaptive reactions to long-term exposure to micro-concentrations of toxic substances.

Thus, for example, at an exposure to average daily concentrations of lead in the air of 1.0 to 2.5 \( \mu g/m^3 \), increased excretion of lead in urine was observed in children, pointing to the presence of lead in blood caused by mobilization of lead in bones.\(^1\),\(^2\)

An increase in the concentration of phenol in the ambient air of a ferrous metallurgy district was reflected in an increased content of free phenol in the urine of children living within 1 km from the plant.\(^3\)

A high, persistent pollution of ambient air by sulfur dioxide, \( SO_2 \) may be detected in blood, indicating an unfavourable influence of this contaminant on the protective functions of a child's organism.\(^4\)

The effects of carbon monoxide pollution can be investigated by measuring the carboxyhaemoglobin concentration in blood. An increase of carboxy-haemoglobin was observed in street traffic regulators (traffic policemen) and in schoolchildren under conditions of high level pollution of ambient air by industrial discharges of carbon monoxide. Polyglobulia was also found; this was accompanied by specific subjective difficulties.\(^5\),\(^6\)

A specific reaction of the organism to the presence of fluorine compounds in air is fluorosis. Its characteristic symptom is the appearance of mottled enamel which could be detected in schoolchildren living in industrial districts (superphosphate and aluminium plants), the degree of the appearance of mottled enamel was correlated to the concentration of fluorine compounds in ambient air and with the length of stay in the polluted area.\(^7\),\(^8\),\(^9\) If such phenomena are observed, it should of course be proved that the level of fluorine in drinking water is such that no pathological effects could arise from this source.

In residential districts situated in the neighbourhood of oil refineries and petrochemical plants discharging aliphatic hydrocarbons (mainly olefines) into the atmosphere, hypotonia, leukopenia and thrombocytopenia were observed in children; these are known as specific effects of unsaturated aliphatic hydrocarbons. When chlorinated hydrocarbons were inhaled, metabolites of tetrachloroethane could be found in the urine of children.\(^10\)

When the effects of suspended matter (fly ashes from power plants,\(^a\) cement dust, asbestos dust, etc.) are investigated, clinical X-ray examination is the basic method to be used. Only those children who are tuberculin-negative should be selected for X-ray examinations. The children should also be subjected to a general medical examination. The analysis of X-ray examination material collected in various studies indicated in some cases the presence of pathological changes which could be classified as being at the threshold of first degree silicosis. A correlation could be established between the length of exposure

\(^a\) Chemical, microscopic and X-ray structure analysis revealed the presence of free silica in fly ashes (in the form of alpha-quartz which is known to be biologically highly active).
to dust and the stage of development of pathological changes (as revealed by X-ray examination). This method can be used for medical investigation of adults persistently exposed to dust in the ambient air.\textsuperscript{13} Summarizing the results obtained by the author and other investigators\textsuperscript{14} it can be stated that fibrotic changes in the lungs can develop not only as a result of occupational exposure (occupational pneumoconiosis) but also as a result of non-occupational exposure (non-occupational pneumoconiosis); these changes are less pronounced and appear as the initial stage of diffuse 'pneumosclerosis'.

Eye injuries caused by suspended particles is another type of direct effect of air pollution on the health of the population.\textsuperscript{18} The frequency of such injuries in patients examined by eye specialists increases with decreasing distance from the source of pollution. Thus, for example, it was recorded in Leningrad that 30 per cent. of patients asking medical help in eye departments of three polyclinics situated at different distances from the power plant,\textsuperscript{11} suffered from such injuries.

Haematological investigations (haemoglobin and methaemoglobin content, erythrocyte, reticulocyte and thrombocyte count; determination of leukocyte forms; colour index; sedimentation) should not be omitted from any investigation into the effects of atmospheric pollutants on the health of the population. Another important method is the examination of phagocytic activity of the blood (phagocyte number, phagocytic index) which may be an indicator of reduced resistance capacity of the organism resulting from chronic exposure to toxic substances in the air.

Investigations carried out in industrial districts pointed to the possibility of using also for such studies some biochemical blood indices (calcium content, inorganic phosphorus, alkaline phosphatase, blood sugar and blood catalase)\textsuperscript{9} and some physiological tests (blood pressure, vital capacity of lungs; determination of odour threshold; determination of the irritating effect of cement dust on the mucous membranes of the nose and the conjunctivae - Jasinovskij's method of washing mucous membranes; determination of the excitability of the vegetative nervous system by oculo-cardiac reflex and orthostatic tests, etc.). The results of such investigations showed that the odour threshold in children increased with decreasing distance of the residential area from a cement factory, particularly, within a zone of 0.5 km (the average dust concentration was 1.48 mg/m\textsuperscript{3}). This is in agreement with some other data showing that the irritating effects of cement dust on nose and eye mucosa increased with decreasing distance from a cement plant, as indicated by the migration of leukocytes to the surface of the mucous membranes and increased desquamation of epithelial cells.\textsuperscript{15,16} Similarly it was shown that cement dust reduces the excitability of the vegetative nervous system.

The effects of microconcentrations of atmospheric pollutants on the health of children can also be studied by investigating the cholinesterase activity, the porphyrin metabolism and the steroid function of suprarenal glands (excretion of 17-ketosteroids in the urine) and by determination of osmotic resistance of the erythrocytes. All these methods enable us to assess early non-specific reactions of the organism to the presence of atmospheric pollutants in the form of functional changes of different degree, similar to the changes observed in experimental animals.\textsuperscript{17}

Summing up this review it can be said that modern air hygiene has a number of different methods which can be used to investigate, in natural conditions, the influence of air pollution on the health of the population. The reaction of the organism may be specific as well as non-specific, from protective and adaptive changes in certain biochemical and physiological indices to the repression of immunological reactivity of the organism leading to increased incidence of illness.
It is obvious that precise numerical values of the concentrations and the exposure times of various substances, and their combinations producing certain biological effects (in particular, changes in the resistance of the organism related to incidence of disease), can only be established by laboratory experiments, under rigidly controlled conditions. However, the results of field studies of the effects of air pollution on the health of the population in combination with laboratory experimental data gives a firm scientific foundation for governmental measures aiming at sanitary protection of the atmospheric environment of inhabited areas.

REFERENCES

1. Gusev, M. I. (1959) Gig. i Sanit., No. 7, p. 41
2. Smirnov, D. D. (1962) Gig. i Sanit., No. 10, p. 8
5. Vol'fson, Z. G. (1952) Maximum permissible concentration of carbon monoxide in ambient air. In: Maximum permissible concentrations of atmospheric pollutants, Moscow, Medgiz, 1, p. 68 (in Russian)
6. Skvorcova, N. N. (1957) Gig. i Sanit., No. 12
10. Krasovickaja, M. L. (1965) Hygienic assessment of ambient air pollution by effluents from oil refineries and petrochemical industry, Moscow (in Russian)
12. Gol'dberg, M. S. (1952) Permissible concentrations of non-toxic dust in ambient air. In: Maximum permissible concentrations of atmospheric pollutants, Moscow, Medgiz, 1, p. 40 (in Russian)
15. Davidov, S. A. (1954) Some physiological changes observed in children living under different conditions of air pollution by cement production (in Russian). In: Materialy Vsesojuznoj konferencii po sanitarnoj ohrane atmosferskogo vozduha, Moscow, p. 59
18. Gol'dberg, M. S. (1955) Gig. i Sanit., No. 1, p. 41
Air Pollution Control Technology
PURIFICATION OF INDUSTRIAL EFFLUENT GAS FROM SUSPENDED MATTER

by

V. N. Uzov

Most of the research and development in the field of industrial effluent gas purification from suspended matter is carried out in the USSR by the Research Institute for Gas Purification of the All-Union Association for Gas Purification and Dust Control (SOJUZGAZOČISTKA). Some special problems of gas cleaning have also been investigated by industrial research institutes. The purification of ventilation air is mainly dealt with by industrial hygiene and sanitary engineering laboratories which are not within the SOJUZGAZOČISTKA organization.

Current developments of dust control installations in power production and in different branches of industry will now be briefly described.

POWER PRODUCTION AND HEATING

Thermal power stations

The development of the thermal power station system in the USSR is characterized by the construction of progressively larger power units; new types of coal are used and new methods of combustion are developed.

Some new types of coal have a high ash content (Ekibastuz coal) or high content of alkaline substances which retain sulfur dioxide produced by burning. Some new boiler aggregates need pre-dried fuel; others are equipped with cyclone type furnaces, or furnaces with liquid slag removal; this tends to reduce the particle size of suspended matter and to increase its specific electric resistance. All this makes the control of grit and dust emission in flue gases more difficult, and new methods for removal of suspended matter are needed. Another complicating factor is the volume of flue gases which increases proportionally with the power of the units; on the other hand the specific surface of the boiler cell, where the gas purification equipment is installed, is progressively reduced. Therefore, the dust control devices must have a high capacity and at the same time a high removal efficiency because the standards for the maximum permissible dust concentration in ambient air - set by the USSR public health authorities - are very rigid.

In the course of the last few years a new type of dust arrester has been installed in Soviet power stations. It consists of horizontal multi-polar electro-filters with trough-like collecting electrodes of PGD and PDGS type, has been designed for gas flow velocities up to 2.2 m/s and reduces the ash content to about 300-500 mg/m³. The collection efficiency is about 98 per cent. The cost of the equipment is about 630 rubles per 1000 m³/h of flue gas (NTP²).

A combined two-stage dust arrester is used in power stations burning anthracite dust, because the flue gases contain significant quantities of unburnt fuel which has to be returned to the furnace. It consists of a battery of direct flow cyclones and a PDG type horizontal electrical precipitator.

² NTP = normal temperature and pressure, i.e. 0°C and 760 mm Hg.
The new electro-filter is supplied by a power-unit with selenium rectifiers and automatic voltage regulation. This type of dust control device is used in power stations with electricity generating units up to 300 MW. Another type of electro-filter is being developed for stations with power generating units from 500 to 800 MW. The height of the collecting electrode will be about 12 m.

Dry inertial separators are also being developed for power stations using peat. In some cases (small power stations) when a dust removal efficiency of 90 per cent. is acceptable dust control is effected by liquid centrifugal scrubbers.

Industrial and heat station boiler plants

Until recently boiler plants operating on various types of coal were equipped with standard 'NIIOGAZ' cyclones (Fig. 2).

These units are simple, reasonably priced and have a dust removal efficiency of 90 to 92 per cent. if the thin bed method of coal burning is used, and about 80 per cent. if coal powder is burned. The cost of such an installation amounts to 130 rubles per 1000 m$^3$/h of flue gas.

NIIOGAZ has now developed a new type of dust arrester — a cyclone battery with tangential gas inlet and recirculation. This is a highly efficient device and takes up little space. It should find wide application in different branches of industry.

Mobile power stations

Mobile power stations (or power trains) represent a considerable source of air pollution. As a rule they have low chimneys and are not equipped with any dust arresting device. NIIOGAZ has now developed a combined smoke and dust arrester for mobile power stations. These devices may find application in some factory boiler rooms where little space is available for other types of installation.

Metallurgy of iron and steel

Open-hearth steel production

Highly efficient installations are needed for removing dust from open-hearth flue gases. The suspended matter consists of condensed metal oxides in a highly dispersed state. The particle size is of the order of 3 microns and rarely exceeds 10 microns. The temperature of the flue gases is about 600 to 650°C. In order to use this heat the gases are passed, before purification, through a boiler system which reduces their temperature to about 250°C. A recent modification of the open-hearth process consists in blowing oxygen through the steel bath. This increases the efficiency of the technological process but at the same time complicates the purification of flue gases considerably because the amount of suspended matter is increased, the particles become smaller and the humidity of gases is reduced. For example, if an oxygen jet is used the concentration of suspended matter increases from 1-3 to 10-12 g/m$^3$. The change in particle size distribution is shown below:

<table>
<thead>
<tr>
<th>Bath without oxygen jet</th>
<th>Bath with oxygen jet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Particle size</strong></td>
<td><strong>Per cent. by mass</strong></td>
</tr>
<tr>
<td>&lt;1</td>
<td>11</td>
</tr>
<tr>
<td>1-3</td>
<td>32</td>
</tr>
<tr>
<td>3-10</td>
<td>37</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>
Another complicating factor is that oxygen blowing increases the electrical resistance of the particles.

Two systems are used for purification of open-hearth flue gases, dry purification and wet purification. The dry purification system consists of multi-polar horizontal electrical precipitators of DGPN type installed after the boiler system. If there is no oxygen blowing, this system operates satisfactorily and reduces the dust content to 100 mg/m³; it costs approximately 1250 rubles per 1000 m³/h of flue gas. Oxygen blowing reduces the efficiency of this system considerably. It has been found, however, that the efficiency of electrical precipitation can be improved by increasing the humidity of the flue gases before purification (injection of steam). By increasing the humidity to 120 to 150 g of water per 1 m³ of dry gas, it was possible to reduce the suspended matter content to about 150 mg/m³. The increase of humidity reduces the specific resistance of the dust and at the same time improves the electrical stability of the precipitator. A recent development in electrical filtration of flue gases from the open-hearth process (with oxygen blowing) is dry horizontal electro-filters with tubular collecting electrodes and needle-shaped discharge electrodes. These installations have proved reliable and efficient.

In some cases (old steel mills) Venturi-scrubbers have been installed because there was not enough space for electro-filters. Liquid scrubbers are simpler in design but it must be pointed out that they produce highly polluted liquid waste which cannot be discharged without preliminary purification. Corrosion prevention problems are also considerable. Moreover, it should be noted that liquid scrubbing has a negative effect on the diffusion of discharged gases and that utilization of collected dust becomes more difficult.

The use of electro-filters is therefore recommended for dust emission control in open-hearth steel production; wet methods should be used only if, for some technical reasons, installation of electro-filters is not feasible.

Converter process

In recent years a large number of high capacity (100 tons) converter units have been put into operation in the USSR. The converters are blasted with oxygen and must be equipped with effluent gas purifiers. The amount of suspended matter in these gases is very large and may be of the order of 2 per cent. of the weight of molten iron. It consists mainly of iron oxides (70 to 75 per cent.). The purification is effected by a wet system - the TPP turbulent scrubber. This highly efficient dust collector is a two-stage installation; the first stage consists of a battery of small pipe sprayers and the second stage of two foam screens. This type of equipment has been used with several converter units both in the USSR and abroad. It reduces the dust content in effluents to less than 100 mg/m³. The cost is approximately 350 rubles per 1000 m³/h of effluent gas.

Electric arc steel furnaces

It is well known that electric arc steel production is steadily increasing. It is also well known that the electric arc steel furnaces are potent air pollution sources, producing a highly dispersed dust of ferric oxide. The particle size distribution depends on the charging method and the smelting technology; 70 to 75 per cent. of particles are below 5 microns. Ferric oxide particles produced by oxygen blast are of the order of 0.01 to 0.2 microns.

A wet gas purification system is used with furnaces of comparatively large capacity (20 tons or more) operating with oxygen. It consists of a hollow (plain) scrubber followed by a turbulent gas washer (Venturi scrubber). A regulating shutter is mounted in the gas duct in front of the scrubber to control the pressure under the cupola of the furnace and ensure that all the gas is exhausted. This system reduces the dust content in the gas to about 100 mg/m³, and costs approximately 670 rubles per 1000 m³/h of effluent.
Until recently small furnaces (3-5 tons) which are usually operated without oxygen had not been equipped with gas purification devices at all. 'NIIOGAZ' has now developed a dry dust control system consisting of an air cooling unit and a glass fibre sleeve filter. Industrial testing of such a system showed that it reduces the dust concentration to 10 mg/m³. Experimental gas purification units for 3-5 ton furnaces are now being built for industrial use.

Ferro-alloy plants

The number of closed furnaces used in the ferro-alloy industry is increasing steadily. Gas purification units for closed furnaces are much more economical than are the dust control devices for open furnaces, since the effluent gas volume is considerably reduced. An open furnace produces 60 000 to 80 000 m³/h of gas-air mixture; the corresponding figure for a closed furnace is only 2000 to 3000 m³/h. The gas produced in closed furnaces is rich in CO and may be used either for heating or for chemical synthesis.

The gas purification system for closed furnaces used in the USSR consists of an inclined sprayed gas duct followed by a hollow scrubber and a Venturi scrubber. These gas purifiers usually operate with a closed water circuit and in pairs; one unit is in operation, the other in reserve. The dust removal efficiency is high, the residual dust concentration being of the order of 30 mg/m³. A study of different operating conditions has revealed that the amount of gas, its temperature and dust content depend directly on the useful power and the useful phase voltage of the furnace; this facilitated the estimation of optimum operating conditions, i.e. when the discharge of dust is smallest. The purified gas has a high caloric value (2500 kcal/m³) and is used for steam production and heating. An economic analysis has shown that using the purified gas from one furnace (2240 m³/h) as fuel pays for the gas purification system in 0.6 years and gives an additional profit of about 29 000 rubles per year. Research into the possibility of using the purified gas from closed furnaces in chemical synthesis is in progress.

CHEMICAL INDUSTRY

Cement production

The main source of air pollution in cement production is the gas discharged from rotary clinker kilns. The amount of dust discharged depends on many factors, such as size and design of the kiln, method of production, roasting conditions, type of fuel, heat exchange system used, and composition and type of raw materials. Usually the amount of dust varies between 5 and 20 per cent. of the material charged into the kiln. The dust concentration in effluent gases varies between 10 g and 50 g/m³ but sometimes it may reach 25 per cent.; 18 to 50 per cent., of particles are below 10 microns.

The control of dust emission from rotary kilns in the wet production process is performed by the new horizontal electro-filters of PDG type which reduce the dust content to 0.1 to 0.15 g/m³. The installation and operating costs amount to about 1300 rubles per 1000 m³/h of gas.

In plants using dry process cement the dust emission from rotary kilns equipped with cyclone heat exchangers is controlled by two systems:

(a) a hollow scrubber followed by a horizontal electro-filter with needle-shaped electrodes;

(b) a fibre glass sleeve filtration.

The dust emission control in cement plants using the dry production process is less effective owing to the operational instability of rotary kilns with cyclone heat exchangers.
Purification of gases emitted by drying units and by cement mills is performed in two stages, the first stage being a group of cyclones, the second a horizontal electro-filter. This system is capable of reducing dust content to 150 to 200 g/m³, with a cost of about 1900 rubles per 1000 m³/hour of effluent.

**Lamp black production**

The tendency of the lamp black industry is to increase the production of highly dispersed lamp black with specific surface of 70-100 m²/g, and this requires highly efficient soot collectors.

If the specific area of the product is larger than 50 m²/g, electro-filtration is inefficient. For plants producing lamp black with 70-100 m²/g a multi-stage gas purification system is needed. It consists of a serial combination of NIiOGAZ cyclones, sleeve filters (siliconized fibreglass fabric) and after-burning. The after-burning system is used for steam production and removes from gases the residual soot as well as combustible gaseous components of the effluent (hydrogen sulfide, carbon monoxide, hydrogen, methane and ethylene).

**Sulfuric acid plants**

Gaseous effluents from chamber and contact sulfuric acid plants, from sulfuric acid concentration plants and from some other chemical production processes contain sulfuric acid mist, an aggressive and noxious contaminant. The basic method of gas purification in such cases is electro-filtration. The sulfuric acid mist content is reduced to 40-250 mg/m³. Different designs of electro-precipitators have been developed for various types of production processes. The cost of installation of electro-filters for removing sulfuric acid mist depends on technological conditions of purification, and varies between 2000 and 7000 rubles per 1000 m³/h of effluent gas.

**Production of chemical fertilizers**

The sources of air pollution in this type of chemical industry are the drying units. The discharge gases contain a large amount of dust, the uptake being between 10 and 20 per cent. of the product. Dust arresters usually consist of several stages. The preliminary stage includes cyclones or batteries of cyclones. Electro-precipitation is usually the second stage and is followed by sleeve filtration. If the sludge is of some commercial value, wet cleaning is used in the second stage - foam units, inclined rotary washers or Venturi scrubbers. By using such a combined system the dust concentration in effluent gases is reduced to 50-100 mg/m³. The cost of dust collecting installations (for instance cyclones combined with horizontal electro-precipitators) is about 2000 rubles per 1000 m³/h of effluent.

**Production processes using powder catalysts**

Powder catalysts are used in a variety of chemical production processes (for instance in 'cracking', for dehydrogenation of butane in the synthetic rubber industry, etc.). Effluents produced in such plants are treated in multistage purification systems. Initial purification is usually performed by a group or a battery of cyclones. This is followed by after-burning in a boiler system, where the temperature of flue gases is reduced from 600 to 300°C. A scrubbing unit forms the third stage, and the gases are cooled down to about 200°C. The final stage is electrical precipitation. The dust concentration in purified effluents does not exceed 40 mg/m³. The cost of the two final stages of purification (scrubbing and electro-filtration) amounts to about 3000 rubles per 1000 m³/h of purified gas.
CONCLUDING REMARKS

There are several engineering approaches to the complex task of ambient air pollution abatement:

1. Use of contained (closed) technological processes in which there are no effluent industrial gases.

Examples

(a) Power-technological utilization of fuels: solid or liquid fuel is gasified. Combustible gases are purified from tars and resins, sulfur compounds, soot and dust and used for fueling boiler systems. In such cases practically no air contaminants are emitted.

(b) Roasting of sulfur containing non-ferrous metal ores should be combined with sulfuric acid production.

(c) Automobile transport in large towns should be replaced by electrical transport facilities.

2. Rational organization of technological processes which may essentially reduce the volume of gaseous effluents as well as the concentration of contaminants in the effluent.

Examples

(a) Application of closed electrolysers in aluminium production could reduce the volume of ventilation air several hundred and even 1000 times. This would simplify the purification problem enormously (aluminium plants, as operated now, produce several million cubic metres of air per hour).

(b) Use of closed furnaces in the ferro-alloy industry and in the production of calcium carbide reduces the volume of gaseous effluents 10 to 20 times which both simplifies the purification technology and enables further use of effluents as fuel gases.

3. Elimination of uncontrolled atmospheric emissions. A significant part of industrial air pollution derives from uncontrolled (or 'unorganized') emissions of air contaminants. They are mainly due to imperfections in technological operations. The principle sources of uncontrolled emission are:

(a) open or insufficiently sealed transportation of powdered materials within the plant;

(b) open storage of dusty raw materials or solid waste products;

(c) uncontrolled disposal of dusty materials.

4. Availability of specialized industry for construction of gas purification equipment.

Experience has proved that the design and construction of gas purification equipment in non-specialized workshops and plants leads to an unsatisfactory quality of equipment. If unqualified mounting is combined with this, results may be very poor indeed. Design, construction and mounting of dust control and gas purification equipment must be undertaken by qualified people and in specialized factories.
REFERENCES


2. Šneerson, B. L. (1950) Electrical purification of gases, Moscow, Metalurgizdat (In Russian)


5. Užov, V. N. (1955) Sanitary protection of atmospheric air, Part I, Moscow, Medgiz (In Russian)


10. Užov, V. N. (1962) Dust abatement in industry, Moscow, Goshimizdat (In Russian)


12. Kučeruk, V. V. (1963) Dust removal from ventilation air, Moscow, Masgiz (In Russian)


15. Užov, V. N. (1964) Safety engineering of electro-filtration in chemical industry, Moscow, Himija (In Russian)

Note: The book listed under 5. has been translated into English by Ben S. Levine (distributed by United States Department of Commerce, Office of Technical Services, Washington D.C.).
Fig. 1  Horizontal multi-polar electro-filters PGD-4-50
Fig. 2  Group of cyclones designed by 'NIIOGAZ'
The control of noxious gases is a very broad subject. The present report is restricted to the methods of controlling some of the most common (sulfur dioxide, hydrogen sulfide, fluorine, chlorine, nitrogen oxides, organic solvents) and the most toxic (tetraethyl lead, mercury, hydrogen cyanide) pollutants.

SULFUR DIOXIDE

In general four methods are used in controlling air pollution by sulfur dioxide:

1. Dispersion of effluent gases through high stacks;
2. Removal of sulfur from fuel;
3. Use of natural gas instead of liquid fuel;
4. Removal of sulfur dioxide from effluents.

The first method is used only if the discharge of sulfur dioxide is comparatively small.

The second method, i.e. the removal of sulfur from solid fuel, does not seem to be very promising. This problem is now being investigated both in the USSR and in the United States of America but the experiments are still at laboratory stage. The removal of sulfur from liquid fuel is theoretically attractive but the industrial application of this process is still remote. Sulfur removal by destructive hydrogenation of liquid fuel is uneconomic because of the high cost of hydrogen.2,3

The third method which consists of replacing liquid fuel by natural gas cleaned from hydrogen sulfide is considered very promising in the USSR, particularly in electricity production and in the petro-chemical industry. Much research is being done in this field, and the first pilot plants have been erected.

The removal of sulfur dioxide from effluent gases is applicable in all branches of industry. Several procedures are used in the USSR depending on the concentration of SO2 in the effluent and on the amount discharged.

The so-called limestone method is used for removing sulfur dioxide from effluents discharged by agglomeration plants if the sulfur content in the ore is small. An example of industrial application of this process is the Abagur Plant in Kuznetsk. The SO2 content in effluent gases is below 0.15 per cent. The sludge containing calcium sulfite and calcium sulfate is not utilized. The principle of this method is well known and consists of binding sulfur dioxide by a suspension of natural limestone. Apart from agglomeration plants this procedure is used in a variety of industrial processes which release small quantities of sulfur dioxide.

The removal of sulfur dioxide from effluents in contact process sulfuric acid plants is based on the absorption of SO2 by a solution of soda or a solution of ammonium sulfite and bisulfite. This process produces a solution of sodium or ammonium bisulfite of commercial value (Voskresenskij Chemical Industry). In one of the contact process sulfuric acid plants, an ozone catalytic method is being investigated.
A cyclic magnesite method is used in the USSR for removing sulfur dioxide from effluents produced by thermo-electric power stations or by agglomeration plants for ores with high sulfur content. The method consists of binding SO₂ by a suspension of magnesium sulfite and magnesium oxide crystals in a solution of magnesium sulfite and bisulfite. Slightly soluble magnesium bisulfite precipitates in the form of rod-shaped crystals which are removed from the solution, dried and roasted at 850°C-900°C. The roasting process decomposes magnesium bisulfite into magnesium oxide and sulfur dioxide. Magnesium oxide is returned to the absorbing suspension and the sulfur dioxide-air mixture (10 to 15 per cent. SO₂) is used for sulfuric acid production. The magnesite method has been tested in two pilot plants. One was installed in an electric power station (capacity 14,000 m³ per hour), the other in an agglomeration plant (8000 m³ per hour). The magnesite method has a removal efficiency of 95 to 97 per cent. Gas cooling and special dust filtration are unnecessary and no useless waste material is produced. Four full-scale industrial installations are now being constructed for purification of agglomeration gases at the Magnitogorsk Steel Plant with a total capacity of about 4000,000 m³. These installations are expected to produce about 150,000 tons of sulfuric acid per year and will be put into operation in 1969.

The second promising technique for sulfur dioxide removal from industrial effluents is the ammonia-autoclave method, in which SO₂ is absorbed by an ammonium sulfite-bisulfite-sulfate solution. The saturated solution with a high content of ammonium bisulfite is treated with sulfuric acid and decomposed in an autoclave at 6 atm and 147°C into ammonium sulfate and elementary sulfur. No gas cooling or dust filtration is needed. The removal efficiency amounts to 93 to 97 per cent. The method has been tested in Great Britain. The Chemical Division of the Research Institute for Gas Purification (NIIOGAZ) has modified this method. The duration of autoclave treatment has been reduced and the yield of elementary sulfur increased. A pilot plant of 50,000 m³ per hour capacity will be constructed in 1968 to obtain the necessary parameters for the design of industrial installations. It must be pointed out, however, that the ammonia-autoclave process is not very attractive from the economic point of view since the product, ammonium sulfate, is a fertilizer of low nitrogen content.

Other methods for removal of sulfur dioxide, investigated at the NIIOGAZ laboratories, are still in the development stage. Three main lines of research are followed:

1. The catalytic oxidation of sulfur dioxide and production of sulfuric acid at high, as well as low, temperatures (about 50°C);

2. The adsorption of sulfur dioxide on carbonless sorbents with thermal regeneration and production of elementary sulfur;

3. Further modifications of the magnesite method.

All these methods will be at the pilot plant stage in 1969.

The following table shows the estimated capital investment and running costs for different SO₂ removal processes as applied to thermal electric power stations.
TABLE 1. ESTIMATED CAPITAL INVESTMENT AND RUNNING COSTS FOR VARIOUS SO₂ REMOVAL METHODS

<table>
<thead>
<tr>
<th>Method</th>
<th>Capital investment (rubles)</th>
<th>Running costs minus the value of by-products (in rubles per ton)</th>
<th>Gross running costs (in rubles per ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>per ton of fuel oil (mazout)</td>
<td>per ton of fuel oil (mazout)</td>
<td>per ton of coal</td>
</tr>
<tr>
<td>1. Limestone</td>
<td>4.3</td>
<td>-1.11</td>
<td>1.11</td>
</tr>
<tr>
<td>2. Ammonia-autoclave</td>
<td>8.1</td>
<td>+0.22</td>
<td>2.42</td>
</tr>
<tr>
<td>3. Cyclic magnesite</td>
<td>6.4</td>
<td>+0.06</td>
<td>1.77</td>
</tr>
<tr>
<td>4. Potash-magnesite</td>
<td>4.8</td>
<td>-0.34</td>
<td>2.04</td>
</tr>
<tr>
<td>5. Ozone-catalytic</td>
<td>3.5</td>
<td>+0.80</td>
<td>0.64</td>
</tr>
<tr>
<td>6. Activated charcoal</td>
<td></td>
<td>4.6</td>
<td>22.21</td>
</tr>
<tr>
<td>with thermal regeneration</td>
<td></td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>7. Absorption by alkaline</td>
<td></td>
<td>4.6</td>
<td>-1.0</td>
</tr>
<tr>
<td>alumina with thermal</td>
<td></td>
<td>32</td>
<td>2.6</td>
</tr>
<tr>
<td>regeneration</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REMOVAL OF HYDROGEN SULFIDE

If the volume of effluents is small and the concentration of hydrogen sulfide is low (about 100 mg/m³) an adsorption on bog iron ore (limonite) is usually applied. The natural ore has to be activated by calcium-hydroxide. When the saturation of the adsorbent reaches 40 to 50 per cent. by weight, it is sent to the sulfuric acid production plants.

Small gas volumes with high concentrations of hydrogen sulfide are treated by a concentrated aqueous solution of caustic soda. The by-product is sodium sulfide which has commercial value. This cleaning method has been applied in the dyestuff industry.

If the volume of effluent is large and the concentration of the contaminant is low (of the order of 100 to 600 mg/m³), the purification is performed either by the 'iron-soda' or the quinone method. In the 'iron-soda' method hydrogen sulfide is absorbed in an alkaline suspension of ferrous hydroxide. In the quinone method the hydrogen sulfide is removed by an alkaline solution of quinone. In both processes the solution is regenerated by blowing air through it under high pressure. The by-product is elementary sulfur. The two processes are technologically very similar. The drawback of the 'iron-soda' process is a high rate of consumption of the absorbing solution. Also, since the product is contaminated with iron hydroxide, its use is restricted. Deposition of solid ferrous hydroxide is another difficulty. The advantage of the alkaline quinone process is that the sulfur produced is very pure. The removal efficiency is satisfactory in both processes, and they are both used in synthetic fibre plants. The capital investment cost is the same (9.8 rubles per ton of staple fibre) but the running costs of the quinone method are lower (5.0 rubles per ton as compared to 6.6 for the 'iron-soda' method).
REMOVAL OF NITROGEN OXIDES

Nitrogen oxides are removed from exhaust gases of chamber process sulfuric acid plants by scrubbing with cooled 70 per cent. sulfuric acid. This procedure reduces the nitrogen oxide content in the effluent to 0.05 per cent.

In the production of dilute nitric acid, nitrogen oxides are removed from gaseous effluents by alkaline aqueous absorbents (calcium hydro-oxide, sodium hydro-oxide, ammonia), yielding nitrogen fertilizers as by-products. This cleaning process reduces the content of nitrogen oxides to 0.1 to 0.3 per cent. The same purification process is also used in dyestuff production.

In the course of the last five years catalytic reduction of nitrogen oxides into nitrogen has been used extensively. The reduction reaction takes place in a carbon dioxide or hydrogen atmosphere at 700 to 750°C in the presence of noble metal catalysts. The catalytic purification process is used in several nitrogen fertilizer production plants.

Silica gel seems to be the only good solid adsorber for nitrogen oxides. The removal of slow concentrations of nitrogen oxides from small volumes of effluents can be achieved by passing the exhaust gases through a mixture of peat and ammonia. The saturated absorber is a good fertilizer.

Research is also being done on the application of different oxidants (potassium permanganate, hydrogen peroxide and ozone) for removing nitrogen oxides. Absorption in an ammonium sulfite solution has also been suggested.

REMOVAL OF FLUORIDES

The main sources of air pollution by fluorides are aluminium production plants and phosphate fertilizer factories.

In the USSR the fluorine compounds are removed from effluent gases either by a single stage process using soda solution or by a two stage process: dust is first removed by electrostatic precipitation and the removal of hydrogen fluoride is achieved by absorption in a solution of aluminium hydroxide and returned to the production process. Ventilation air is not cleaned because its volume is enormous owing to the leakage of electrolyzers. Research is now being conducted on the binding of fluorine compounds by injecting powdered magnesium or calcium oxide into the cooled (below 0°C) ventilation air stream.

CHLORINE AND CHLORINE COMPOUNDS

The main sources of air pollution by chlorine and chlorine compounds are non-ferrous metallurgical plants (production of magnesium lithium and titanium) and some chemical industries (production of chlorine, perchlorates, organic chlorine compounds).

The traditional method of absorbing chlorine by lime is still widely used. It has a high removal efficiency (95 to 98 per cent.). The absorption takes place in scrubbers washed by milk of lime. The resulting liquid waste, containing calcium hypochlorite, is purified either by a catalytic method or by the 'saw-dust' treatment.

Aqueous solution of ferrous chloride is used for removing low concentrations of chlorine from small volumes of effluent. The by-product is ferric chloride. The method is rarely used because the demand for ferric chloride is limited. Another method consists in absorbing chlorine by ferrous sulfate. The product is ferric sulfate which has a wide application in the production of catalysts and adsorbers. An alternative procedure is to remove small concentrations of chlorine by liquid lignin. Chlorinated lignin is used in the production of ion-exchange resins.
Different chlorine compounds (ethyl chloride, vinyl chloride, ethane dichloride, chlorobenzene, etc.) are removed from gases by adsorption on activated charcoal. There is a large research programme in this field at the Dzeržinsk branch of NIIOGAZ.

MERCURY VAPOUR AND ORGANIC MERCURY COMPOUNDS

NIIOGAZ laboratories have developed a method for removing mercury vapour from ventilation air. The process is used in many plants. Mercury vapours are bound by natural pyrolusite. The removal efficiency is about 96 to 98 per cent. The saturated sorbent (one per cent. by weight) is used for the production of mercury but it may also be regenerated on the spot. Another method for removing mercury vapour is adsorption by chlorinated charcoal, with subsequent thermal regeneration. The adsorption capacity amounts to five to six per cent. Organic compounds of mercury are adsorbed on activated charcoal. The capacity is about 15 per cent. by weight. The charcoal is regenerated by heating at 500°C, and metallic mercury is obtained.

CATALYTIC PURIFICATION OF EFFLUENTS

Industrial effluent gases are often contaminated with various organic compounds such as butyl aldehyde, methanol, acetone, ethyl mercaptane, benzene, phenol, which can be removed by catalytic combustion. Catalytic combustion of odoriferous substances is used in the USSR in various industries, for example in the production of fatty acids and petroleum bitumens. Carcinogenic substances found, for example, in the effluents of the petroleum bitumen production process, can also be removed by catalytic combustion. Extensive research has been carried out in the USSR to develop cheap, effective and durable combustion catalysts.

REFERENCES

Air Pollution by Fossil Fuel Burning and by Motor Vehicles
COMBUSTION OF MINERAL FUEL AS A SOURCE OF AMBIENT AIR POLLUTION

by

R. S. Gil'denskjol'd

The most widely distributed and powerful sources of urban air pollution are various solid and liquid fuel combustion installations (domestic appliances; central heating and industrial boilers; district heating stations; electric power stations). Effluents from combustion installations using solid fuel have a complicated composition, the main constituents being nitrogen, carbon monoxide, carbon dioxide, oxides of sulfur, mineral dust, particles of unburnt fuel, soot and various organic compounds (tar, resinous matter, hydrocarbons, organic acids, aldehydes, etc.). From the health point of view the most important components of this mixture are the oxides of sulfur, carbon monoxide and suspended solids.

The biological effects of sulfur dioxide are fairly well known. The 50% lethal concentration (100 hour exposure) for most laboratory animals is about 300 mg/m³. Prolonged exposure of animals to concentrations exceeding 120 mg/m³ causes loss of weight and changes in blood composition; reduces the general resistance of the organism; leads to serious metabolic disturbances (acidosis, hyperglycaemia) and affects blood forming organs. In man, periodic exposure to high concentrations of SO₂ (80 to 260 mg/m³) damages the sense of smell and of taste; increases the sensitivity to other irritants; induces nasopharyngitis and has a tendency to increase fatigue. The odour threshold has been reported to be somewhere between 0.9 and 1.6 mg/m³, and the threshold for reflex reaction of the cerebral cortex at about 0.6 mg/m³. Consequently, the maximum permissible concentration, which takes into account the damaging effects of sulfur dioxide on plants as well, has been set in the USSR at 0.5 mg/m³ for (single) exposure at any time and at 0.15 mg/m³ for the daily average exposure.

Depending on meteorological conditions urban air also contains variable amounts of sulfuric acid mist (about 3.2 to 15 per cent, of sulfur dioxide present). Persistent foggy weather tends to increase the concentration of sulfuric acid mist. Sulfuric acid aerosol is more toxic than sulfur dioxide. Lc₅₀ (eight hours exposure) for guinea-pigs is about 18 mg/m³; when exposed to 8 mg/m³ for five days, guinea-pigs showed pathological changes in the lungs tending to develop into fibrous tissue as a result of impaired blood supply to the lung tissue. The odour threshold is at 0.7 mg/m³, the electrocortical reflex reaction threshold at 0.4 mg/m³. The maximum permissible concentrations in ambient air have been set at 0.3 mg/m³ (single MPC) and at 0.1 mg/m³ (24-hour average MPC). The effects of super-threshold concentrations of sulfur dioxide and sulfuric acid are additive.

Suspended matter consists predominantly of aluminosilicates, although iron, calcium and magnesium oxides are also present. Thus, for example, the average composition of ashes from Moscow basin coal was found to be: 45.5 per cent SiO₂; 36.3 per cent. Al₂O₃; 13.1 per cent. FeO₃; 4.4 per cent. CaO; 0.7 per cent. MgO; 3.3 per cent. SO₂; remainder 0.7 per cent. The silica content of coals is sometimes even higher, up to 51.1 per cent. (coal from Kuznec coal basins), 24 per cent. being free silica. Mineral dust, collected 1 km from a thermo-electric plant (using Moscow coal), contained 18.5 to 22.8 per cent. free silica. Gol'dberg found pre-silicotic changes in persons living in areas where ambient air was polluted by free silica. Aerosols also have an indirect effect on health by influencing the local climate unfavourably: foggy weather occurs more frequently; insolation is reduced (particularly the intensity of UV radiation) and visibility is diminished. Soot reduces visibility noticeably at a concentration exceeding 0.05 mg/m³. (This value has been adopted in the USSR as the daily average maximum permissible concentration.) The maximum permissible concentrations of suspended matter have been established at 0.50 (single MPC) and 0.15 mg/m³ (daily average MPC). The suspended matter
contains about 30 per cent. of organic substance. The presence of resinous material in suspended matter is of particular interest since it contains various carcinogenic compounds. The concentration of 3,4-benzpyrene in resinous material fluctuates between 0.005 and 0.01 per cent. and the content of resin in the suspended matter varies between two and seven per cent. If we assume a dust concentration of 0.35 mg/m$^3$ with five per cent. resin, the concentration of 3,4-benzpyrene would amount to $8.7 \times 10^{-4} \mu g/m^3$, corresponding to a daily dose of 0.013 $\mu g$; this is significantly below the toxic limit.

The property of carbon monoxide to form carboxy-haemoglobin is well known. At 20 to 25 per cent. saturation of blood with carbon monoxide, a reduction of blood sugar has been observed. The higher nervous activity of experimental animals was found to be impaired if they were exposed to 20-30 mg/m$^3$ of carbon monoxide six hours per day for 75 days. The maximum permissible concentration for CO in the USSR has been set at 3.0 and 1.0 mg/m$^3$ for the single and the daily average exposures, respectively.

The amount of combustion products in the discharge from fuel burning installations depends on the amount of fuel used and its properties; on the design of furnaces, firing equipment and boilers; and on the efficiency of the dust arresting appliances available. The air pollution level in the breathing zone will also depend on the height of stacks, on the distribution of pollution sources, local topography, meteorological conditions, and the amount and type of vegetation in the area.

Characteristic properties of some solid and liquid fuels used in the USSR are summarized in Table 1.

The most unsatisfactory type of solid fuel, both from the technological and the sanitary points of view, are brown coals and lignites. The water content is high and so usually is the ash and sulfur content; on the other hand, the calorific value is low. Nevertheless, the prospective development of thermal power production in the USSR is based entirely on the enormous reserves of Siberian brown coal. Bituminous shales and peat are typical local fuels. Heavy fuel oil (mazout) has a high calorific value but the type mostly used in the USSR has a high sulfur content (three to four per cent.).

Although the type of fuel has considerable influence on the amount and composition of flue gases, the decisive factor is the design of the furnace and the firing method used. In principle, any fuel can be burnt without emission of smoke provided it suits the design of the combustion appliance. Modern combustion appliances can be broadly classified into two types: bed furnaces and chamber furnaces. Bed furnaces are suitable only for solid fuel which is fed to the grate by various, usually mechanical, methods (for example travelling or chain grate stokers; under-feed stokers). Chamber furnaces consume pulverized solid fuel, liquid and gaseous fuel. They may also be adapted for peat and shale burning. There are two types of chamber furnaces: the torch furnace and the cyclone furnace.

The emission of dust and grit in bed firing, amounts to 20 to 30 per cent. of the total ash content; large particles (up to 50 microns) predominate; 20 to 30 per cent. of the solid matter discharged is unburnt fuel. In pulverized fuel firing units ('dry bottom' type) the discharge is about 85 per cent. of total ash content; this amount can be reduced to 30 to 40 per cent. if 'slag tap' furnaces are used but the dispersion of the suspended matter increases. (About 80 per cent. of particles are smaller than 5 microns.) According to data obtained by the Erisman Institute of Hygiene in Moscow, the content of unburnt fuel in the discharged solid matter is extremely variable (1.5 to 30 per cent.).

The new, very economical cyclone furnaces have a high thermal efficiency (up to $6 \times 10^5$ kcal/m$^3$/hour) and low emission of dust and unburnt fuel. The high temperature (1800°C) developed in a small volume and intense turbulent flow of gases ensure a thorough combustion and an efficient dust collection; the combustion efficiency may attain 85 to 90 per cent., the fraction of unburnt fuel particles in the discharge not exceeding 1.0 to 1.5 per cent. (experimental data).
## TABLE 1. PROPERTIES OF SOME SOLID AND LIQUID FUELS USED IN THE USSR

<table>
<thead>
<tr>
<th>Fuel Source</th>
<th>Moisture Content</th>
<th>Ash Content</th>
<th>S/S P/ Org</th>
<th>C</th>
<th>H</th>
<th>N/O</th>
<th>Volatile matter**</th>
<th>Lower calorific value (kcal/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donec basin, AS</td>
<td>7.0</td>
<td>16.7</td>
<td>1.1/0.6</td>
<td>70.5</td>
<td>1.4</td>
<td>0.8/1.9</td>
<td>4.0</td>
<td>6 010</td>
</tr>
<tr>
<td>Kuznec basin, SS</td>
<td>7.0</td>
<td>7.4</td>
<td>0.4</td>
<td>71.0</td>
<td>4.5</td>
<td>2.0/7.7</td>
<td>30.0</td>
<td>6 440</td>
</tr>
<tr>
<td>Baskir ASSR, Celjabinsk coal, B</td>
<td>17.0</td>
<td>24.9</td>
<td>0.7/0.5</td>
<td>41.8</td>
<td>3.0</td>
<td>1.0/11.1</td>
<td>43.0</td>
<td>3 770</td>
</tr>
<tr>
<td>Moscow basin coal</td>
<td>33.0</td>
<td>23.5</td>
<td>1.7/1.2</td>
<td>29.1</td>
<td>2.2</td>
<td>0.6/8.7</td>
<td>45.0</td>
<td>2 510</td>
</tr>
<tr>
<td>Krasnojarskij Kraj, Nazarov Coal, B</td>
<td>40.0</td>
<td>7.2</td>
<td>0.6</td>
<td>37.2</td>
<td>2.6</td>
<td>0.4/12.0</td>
<td>48.0</td>
<td>3 060</td>
</tr>
<tr>
<td>Estonian SSR, bituminous shales</td>
<td>15.0</td>
<td>51.2</td>
<td>1.1/0.4</td>
<td>25.0</td>
<td>8.2</td>
<td>0.1/4.0</td>
<td>90.0</td>
<td>2 720</td>
</tr>
<tr>
<td>Peat, pieces</td>
<td>40.0</td>
<td>6.6</td>
<td>0.2</td>
<td>30.9</td>
<td>3.2</td>
<td>1.3/17.8</td>
<td>70.0</td>
<td>2 560</td>
</tr>
<tr>
<td>Peat, cut</td>
<td>50.0</td>
<td>5.5</td>
<td>0.1</td>
<td>25.7</td>
<td>2.7</td>
<td>1.1/14.9</td>
<td>70.0</td>
<td>2 030</td>
</tr>
<tr>
<td>Mazout, low S</td>
<td>3.0</td>
<td>0.3</td>
<td>0.5</td>
<td>85.3</td>
<td>10.2</td>
<td>0.7</td>
<td>-</td>
<td>9 310</td>
</tr>
<tr>
<td>Mazout, high S</td>
<td>3.0</td>
<td>0.3</td>
<td>2.9</td>
<td>83.4</td>
<td>10.0</td>
<td>0.4</td>
<td>-</td>
<td>9 170</td>
</tr>
</tbody>
</table>

* Weight per cent. of fuel "as delivered" (not dried).

** Weight per cent. of combustible matter.

S org Organic sulfur; S p : pyrite sulfur.

C: Carbon content; H: hydrogen content; O: oxygen content.

The discharge of dust and grit can be estimated from the formula $A_d = 0.1 A_f a_d$ g/kg where $A_d$ is the discharge of grit and dust in grams per kg of burnt fuel; $A_f$ is the ash content in the fuel 'as received', i.e. weight per cent.; $a_d$ is the relative dust and grit discharge (per cent. of total ash content in the fuel). For example, if the total ash content amounts to 30 per cent. and the fuel is burnt in pulverized form in a double chamber with 'slag tap' the estimated dust burden of flue gases would be $A_d = 0.1 \times 30 = 90$ g/kg. The dust concentration in flue gases is calculated from the dust burden and the volume of gases discharged.

The amount of unburnt fuel discharge in coal dust furnaces can be estimated from the formula $C_u = 25 - 0.5 y r$ where $C_u$ is the per cent. content of unburnt fuel in the suspended matter discharged and $y$ the relative content of combustible matter in the fuel (weight per cent.).

The content of sulfur dioxide in flue gases depends on the amount of sulfur in the fuel, and the firing method. In bed firing, 75 to 80 per cent. of sulfur is oxidized to SO2 and the rest remains in the slag. In pulverized fuel firing, practically all combustible sulfur is transformed into sulfur dioxide; only one to three per cent. of SO2 is oxidized to sulfur trioxide.
Until recently bed firing was used extensively in central heating boilers as well as in industrial boilers. In 1956, in Moscow alone there were between 430 000 and 450 000 heating installations (90 per cent. were domestic appliances). Since then, this type of heating has gradually been eliminated and replaced by gas and district heating. Until this programme had been implemented, air pollution in large cities from domestic appliances exceeded the pollution from industrial sources. Thus, for example, in 1948 the concentration of sulfur dioxide in a comparatively clean residential district in Leningrad amounted to 0.07 mg/m$^3$ in the summer time; during the heating period it increased to 0.36 mg/m$^3$.

Table 2 compares the average degree of air pollution (as measured by SO$_2$ and dust concentration) in Moscow in 1956, 1959 and 1962; a steady decrease of the pollution level, due to gradual introduction of natural gas both in domestic and in industrial combustion installations, is obvious.

<table>
<thead>
<tr>
<th></th>
<th>1956</th>
<th>1959</th>
<th>1962</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>District</strong></td>
<td>SO$_2$</td>
<td>dust</td>
<td>SO$_2$</td>
</tr>
<tr>
<td>Industrial</td>
<td>0.84</td>
<td>0.98</td>
<td>0.37</td>
</tr>
<tr>
<td>Residential</td>
<td>0.84</td>
<td>0.74</td>
<td>0.34</td>
</tr>
</tbody>
</table>

The organic content of suspended matter in flue gases is due mainly to incomplete combustion in small heating installations. Gurinov showed that the concentration of 3,4-benzpyrene in flue gases emitted by hand-fired installations may reach 0.01 per cent. In steam-raising plants equipped with mechanical firing devices it does not exceed 0.005 per cent. Chamber furnaces emit 3,4-benzpyrene in trace concentrations, only during the unstable phase of combustion (heating-up period). The concentration of resinous substances in flue gases depends on the firing method, and amounts to 3.5 to 5.3 per cent.; 0.8 to 3.4 per cent. and 0 to 0.2 per cent. for hand firing, mechanical firing and chamber furnaces, respectively. The content of resinous substances in the discharge is increased if oil refining products are used as fuel (the concentration of 3,4-benzpyrene is of the order of 0.01 per cent.).

It should also be pointed out that central heating boilers are not usually equipped with dust control appliances, and that their stacks are low. The consequences of these design deficiencies are clearly demonstrated by the following example: a powerful thermo-electric power plant discharges through high stacks up to 360 tons of SO$_2$ daily; the chimney of a central heating plant emits only about seven tons of sulfur dioxide daily but the ground level pollution of ambient air in the immediate vicinity of the heating plant is significantly higher, as shown in Table 3.
TABLE 3. GROUND LEVEL CONCENTRATIONS OF SULFUR DIOXIDE IN THE VICINITY OF A POWER STATION AND A CENTRAL HEATING PLANT

(Daily sulfur dioxide emission: power plant - 360 tons; heating plant - 7 tons)

<table>
<thead>
<tr>
<th>Distance from the source (km)</th>
<th>Sulfur dioxide concentrations in mg/m³</th>
<th>Power station</th>
<th>Heating plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Average</td>
<td>Maximum</td>
</tr>
<tr>
<td>0.2-0.5</td>
<td>4.90</td>
<td>3.00</td>
<td>11.97</td>
</tr>
<tr>
<td>0.3</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
</tr>
<tr>
<td>0.5-1.0</td>
<td>5.50</td>
<td>2.70</td>
<td>0.60</td>
</tr>
<tr>
<td>1.0-2.0</td>
<td>2.80</td>
<td>1.60</td>
<td>0.20</td>
</tr>
</tbody>
</table>

A technological and environmental health study of small boiler plants has proved that the general development plan, adopted in the USSR, to replace small central heating plants by district heating, to use natural gas as industrial fuel and to construct large isolated power stations, has been a correct one. The perspective plan for electrification of the USSR anticipates an increase in the electric energy potential of the country to a total of three thousand billion kWh by 1980. Approximately 80 per cent. of electric energy will be generated by thermal power stations with individual power units of 500 to 800 kW (steam parameters: 240 atm, 580°C). Soviet industry is already producing boilers with a capacity of 950 ton/h; 1600 ton/h and 2500 ton/h boilers are in the design stage.

In the period from 1961 to 1965 a comprehensive study was made of the zonal distribution of ambient air pollution in the vicinity of large power stations. A detailed record was kept of meteorological parameters and plant operating conditions. The results showed that the zone of heavy air pollution around power plants with a fuel consumption of 700 ton/h and a stack height of 120 to 180 m extended up to 15 km. The mean dust emission was of the order of 15 to 17 ton/h, with a maximum value of about 50 ton/h. Air samples were collected simultaneously at 15 to 20 points at distances up to 20 km. The maximum concentrations of sulfur dioxide amounted to 2.53 to 4.03 mg/m³ and were found at a distance from 1 to 6 km from the source (the 'pollution zone'). In the zone of highest ground level dust concentration, 68.5 per cent. of the particles had an average diameter of less than 5 microns. These studies included clinical examination of child populations living in three districts with different air pollution levels as well as a statistical analysis of out-patient departments turn-over records.

Some useful conclusions were reached with regard to general principles of town planning. A large city should be located outside the 'pollution zone' of the power plant even if the estimated pollution level within the zone is of the order of the MPC, because exceptionally unfavourable meteorological conditions and perspective development of the station should be taken into account. The residential area for plant operating personnel may be situated within the 'discharge zone' but the minimum distance from the plant should be of the order of 1000 m.

The new high temperature combustion methods will certainly reduce the air pollution problem but the appraisal of these developments from the health point of view is a matter for the future.
During the last few years exhaust gases from petrol and diesel engines have been analysed both in the USSR and abroad, by chromatography, infra-red analysers, spectroscopy and traditional chemical methods. These studies revealed that the exhaust gases and crankcase emissions consist of a large number of components, an incomplete list of which is given in Table 1.

The quantitative composition of exhaust gases from petrol engines differs essentially from that of diesel engines as shown in Table 2.

There is also a marked difference in the content of toxic components. While the concentration of carbon black (soot) in exhaust gases of diesel motors is about 20 times higher than that in petrol engine exhausts, the content of carbon monoxide is 20 times higher in petrol engine exhaust gases. It has been generally accepted that carbon black, containing carcinogenic substances, is potentially the most dangerous component of diesel exhausts. Oxides of nitrogen present a potential hazard from diesel engines also while aldehydes, hydrocarbons and carbon monoxide are of minor interest. On the other hand, the most important toxic components of petrol engine exhausts are carbon monoxide, hydrocarbons and aldehydes; crankcase gases and fuel vapour leaking from the carburettor system and fuel tanks are considerable sources of air pollution. (Approximately 65 per cent. of air pollution is due to exhaust gases, 20 per cent. to crankcase gases, 9 per cent. to fuel vapours from the carburettor and 6 per cent. to evaporation of fuel from the fuel tank.) As the author and his collaborators (R. V. Malov, R. V. Gargal and F. F. Maculskij) showed experimentally, the relative content of different toxic components in diesel engines depends on the engine power output. This is illustrated in Fig. 1.

Experiments also showed that for the petrol engine the amount of carbon monoxide in exhaust gases depends only on the air-fuel ratio. (Fig.2) In collaboration with A. I. Frenkel, the author derived a multiple regression equation describing the emission of oxides of nitrogen as a function of operating parameters of a petrol engine. Numerous investigations carried out both in the USSR and in the United States of America showed that the emission of hydrocarbons (including carcinogenic compounds) in petrol engine exhausts depends on the air-fuel ratio and the inlet manifold vacuum. At high values of the inlet manifold vacuum the emission of hydrocarbons increases sharply.

On the basis of statistical studies of motor vehicle traffic patterns in cities, it has been possible to carry out chassis dynamometer (revolving drum) tests simulating the real conditions of city traffic. Such programmes have been developed in the United States of America, in Western Europe and in the USSR taking into account specific conditions of motor vehicle transport in these countries. Data obtained made it possible to define more accurately the problem of air pollution by motor exhaust gases, and to select research programmes which are of most value from the practical point of view.

The proper regulation of the fuel system ensuring a high air-fuel ratio should considerably reduce the discharge of carbon monoxide, hydrocarbons and aldehydes into the atmosphere. As experimental investigations showed, there are several practical methods to adjust the carburettor in such a way as to reduce significantly the toxicity of motor vehicle exhaust gases when the engine is idling or operating at low power output. Several devices have been designed and constructed which practically solve the problem of toxic gas emission during periods of forced idling. (In the USSR such devices have been called "discharge regulators with idling economizers"). As is well known, the peculiarities of carburettor vehicles require a low air-fuel ratio to produce high power output, and modern carburettors are adjusted to operate with the throttle valve 80 to 100 per cent. open.
It seems quite feasible to switch, within a given power range, from a quantitative to a qualitative regulation by injection of air. Experiments carried out by the author showed that detonation can be eliminated completely by using high air-fuel ratios. Research on the possibility of burning mixtures with very high air-fuel ratios is of great practical significance; solutions have been proposed in the USSR based on pre-chamber torch ignition and on 'layer by layer' ignition.

It is also well known that anti-knock substances contain tetraethyl lead which contributes to the discharge of significant amounts of very toxic lead compounds. The USSR is the only country where the use of tetraethyllead is legally prohibited in large cities.

Various methods of after-burning of exhaust gases are widely used. One of the essential characteristics of such methods is the supply of additional air to the after-burner when the engine is operating on rich fuel-air mixtures. Catalytic converters are highly efficient devices for eliminating carbon monoxide hydrocarbons and aldehydes from exhaust gases under various operating conditions of the engine. Field experiments showed that the useful life of such devices is long enough (30 000 km or more), and maintenance requirements, minimal. Small size and suitable design made it easy to incorporate a 'neutralizer' into the automobile.

A problem which still needs further research is the elimination of oxides of nitrogen from petrol engine exhausts. Various solutions to this problem have been proposed:

Recycling of a part of exhaust gases to the combustion chamber (semi-closed circuit operation) of petrol engines significantly reduces the content of oxides of nitrogen in the exhausts. Good results have also been obtained by spraying the inlet manifold of the vehicle with water. According to the experience of the author, it seems promising to operate the engine on fuel rich mixtures (which ensure a low nitrogen oxides content) and after-burning incomplete combustion products. Another method which gives satisfactory results consists of adsorption purification of exhaust gases using natural or synthetic zeolites. However, these experiments are still in the laboratory stage.

Many attempts have been made to design an efficient exhaust system for the crankcase. The operational principle of such devices is to pass crankcase gases either to the inlet manifold or to the air-filter, or both. The latter method seems to be the most efficient under all engine operating conditions. The author also believes that burning of crankcase gases in a catalytic converter is a feasible control method.

All efforts in controlling diesel-engine exhausts are concentrated on reducing the emission of smoke. Soot is discharged by two- and four-stroke diesel engines is a polydisperse system. The primary particles are spherical and their size (about 200 to 800 Å) does not depend either on the type of the diesel motor (two- or four-stroke) or the operating conditions. The particles discharged are chains or aggregates of these primary particles. Up to 98 per cent. of soot particles in the exhaust gases are irregular and have a size of about 0.4 to 5.0 microns. Knowledge of physicochemical properties of soot particles made it possible to develop combined control devices based on special types of filters. Such units completely remove the soot from diesel exhaust gases under all operating conditions. Another method for reducing smoke discharge from diesel engines is to use special fuel additives. Several publications by the author and his collaborators point out that one of such additives reduced the emission of carcinogenic substances into the atmosphere by 60 to 80 per cent.

Promising results have been obtained in the USSR by using catalytic converters for reducing smoke emission. Extensive use has been made in the USSR mining industry of the following devices for removal of gaseous toxic components from diesel-engine exhausts:

- In the USSR terminology after-burners, catalytic converters and similar devices are called 'neutralizers'.
(a) Liquid absorbers using different chemical reagents for retaining toxic components. They are used mainly for removing aldehydes and (partly) oxides of nitrogen; the main drawbacks of such devices are bulkiness, considerable weight and complicated operation. Another deficiency of liquid absorbers is that they do not retain carbon monoxide.

(b) Catalytic converters. They are reliable when operated at temperatures above 250°C. In spite of the fact that the efficiency of catalytic converters is reduced if diesel engines are idling or operating at low load, the small weight, high degree of reliability and comparatively low cost of such devices have made them widely used.

(c) Combined control devices. In some instances it has been found advantageous to use combinations of liquid absorbers and catalytic converters; catalytic converters and flame after-burners, etc.

Table 3 summarizes certain characteristics of some power production units used today and contemplated for the future.

<table>
<thead>
<tr>
<th>Table 1. Composition of exhausts from internal combustion engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
</tr>
<tr>
<td>Oxygen</td>
</tr>
<tr>
<td>Hydrogen</td>
</tr>
<tr>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>Water vapour</td>
</tr>
<tr>
<td>Carbon monoxide</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
</tr>
<tr>
<td>Formaldehyde</td>
</tr>
<tr>
<td>Acetaldehyde</td>
</tr>
<tr>
<td>Acrolein</td>
</tr>
<tr>
<td>Carbon black (soot)</td>
</tr>
<tr>
<td>3,4-benzpyrene</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
</tr>
<tr>
<td>Carbon disulfide</td>
</tr>
<tr>
<td>Methane</td>
</tr>
<tr>
<td>Ethane</td>
</tr>
<tr>
<td>Propane</td>
</tr>
<tr>
<td>n-Butane</td>
</tr>
<tr>
<td>Iso-butane</td>
</tr>
<tr>
<td>n-Pentane</td>
</tr>
<tr>
<td>n-Hexane</td>
</tr>
<tr>
<td>n-Heptane</td>
</tr>
<tr>
<td>n-Octane</td>
</tr>
<tr>
<td>Iso-Octane</td>
</tr>
<tr>
<td>n-Nonane</td>
</tr>
<tr>
<td>n-Decane</td>
</tr>
<tr>
<td>2-methylpentane</td>
</tr>
<tr>
<td>3-methylpentane</td>
</tr>
<tr>
<td>2-methylhexane</td>
</tr>
<tr>
<td>3-methylhexane</td>
</tr>
<tr>
<td>2,3-dimethylbutane</td>
</tr>
<tr>
<td>2,4-dimethylpentane</td>
</tr>
<tr>
<td>Components</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Nitrogen</td>
</tr>
<tr>
<td>Oxygen</td>
</tr>
<tr>
<td>Water vapour</td>
</tr>
<tr>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>Carbon monoxide</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
</tr>
<tr>
<td>Hydrocarbons</td>
</tr>
<tr>
<td>Aldehydes</td>
</tr>
<tr>
<td>Carbon black (soot)</td>
</tr>
<tr>
<td>3,4-benzpyrene</td>
</tr>
</tbody>
</table>
TABLE 3. CERTAIN CHARACTERISTICS OF POWER UNITS USED TODAY AND CONTEMPLATED FOR THE FUTURE

<table>
<thead>
<tr>
<th>No.</th>
<th>Source of power</th>
<th>Efficiency on wheels (per cent.)</th>
<th>Spec.weight kg/HP</th>
<th>Air pollution potential</th>
<th>Noise level</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Piston IC engine</td>
<td>10 - 25</td>
<td>1.0 - 4.5</td>
<td>high</td>
<td>high</td>
<td>T. G. Kirkland, L. Gaddy, D. Roesler, IEEE Transactions on Industrial Electronics No. 1, 1965</td>
</tr>
<tr>
<td>2</td>
<td>Rotary engine</td>
<td>9 - 14</td>
<td>0.3 - 1.5</td>
<td>high</td>
<td>high</td>
<td>F. Picard SAE Preprint, 1965, No. 980A</td>
</tr>
<tr>
<td>3</td>
<td>Gas turbine</td>
<td>8 - 12</td>
<td>0.8 - 2.5</td>
<td>average</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Battery operated electric power motors</td>
<td>20 - 40 (depending on efficiency of charging battery)</td>
<td>lead: 42</td>
<td>none</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Fuel elements</td>
<td>50 - 65 (efficiency of power transmission to wheel unknown)</td>
<td>6 - 20</td>
<td>none</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Thermo-electric generators</td>
<td>4 - 17 (no account of efficiency of transmission)</td>
<td>5 - 33</td>
<td>medium</td>
<td>medium</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Thermo-electronic transformers</td>
<td>10 - 20 (no account of efficiency of transmission)</td>
<td>1.5 - 2.5</td>
<td>medium</td>
<td>medium</td>
<td></td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY

1. Korenev, M. S. (1962) Methods for reducing the toxicity of motor vehicle exhausts. CINTIMAŚ, Series XII, Moscow (In Russian)


Fig. 1  Relative content of some toxic components of diesel engine exhausts vs. engine power output

Single cylinder unit

- first series
- second series
- third series

Fig. 2  Carbon monoxide concentration in the exhausts of a petrol engine vs. excess air coefficient

Solid curve obtained by calculations.
When considering the nature of toxicity of exhausts from internal combustion engines and automobiles, one must first determine the role of each toxic substance generated by the engine. Since the largest quantity of toxic substances is discharged through the exhaust, this source of air pollution will be considered primarily. Analyses of exhaust gases showed that they contain about 200 different components (for an incomplete list see Table 1 of Professor Varšavskij's lecture). The non-toxic substances found in automobile exhaust gases are nitrogen, oxygen, hydrogen, carbon dioxide and water vapour. The toxic components may be classified into four groups. The first group contains carbon monoxide only. The second group usually includes oxides of nitrogen; the aldehydes form the third group. (At present it is known that exhaust gases contain formaldehyde, acetaldehyde and acrolein.) The fourth and the largest group are hydrocarbons (representatives of all the main homologous series - alkanes, alkenes and their isomers, cycloalkanes and alkadienes; aromatic hydrocarbons including polycyclic hydrocarbons such as 3,4-benzpyrene).

The great variety of substances found makes it desirable to express the toxicity of the mixture by a single numerical index. This is also important because the concentrations of various substances depend on the engine adjustment and its operating conditions. Fig. 1 illustrates, for instance, how the concentrations of the four main groups of toxic substances change with the air-fuel ratio. (Each group has been evaluated on the basis of the concentration of one of its components.)

It is fairly obvious that the effects of different substances on the human organism cannot be compared directly since each of them exhibits a specific toxic effect. On the other hand, nearly all toxic substances have a common property. If the concentration is reduced below a certain value (threshold concentration), there will be no harmful effects. This means that any quantity of a toxic substance in a gas mixture can be made harmless to the human organism if its concentration is reduced by dilution with the appropriate amount of clean air. Thus, the toxicity of given substances may be expressed in terms of the volume of air needed to reduce its concentration below the threshold value. It goes without saying that this index of toxicity has in itself no meaning from a biological or medical point of view, but it shows in a quantitative way what has to be done to reduce or remove the hazard. Mathematical analysis showed that if several toxic substances are present in a gas mixture, the amount of air required to reduce its toxicity to the threshold level is equal to the sum of air volumes that would be needed for reducing the concentration of each of the components of the mixture to its own threshold limit. The volume of air needed may be calculated from the equation:

\[ V_b = V_{rc} \sum_{i=1}^{i=z} \frac{c_i}{c_i^0} \]

where

- \( V_b \) = the volume of air required for dilution of the mixture to the toxic limit
- \( V_{rc} \) = the volume of the gaseous mixture containing components
- \( c_i \) = the concentration of the \( i \)-th component of the mixture
- \( c_i^0 \) = maximum permissible concentration of the \( i \)-th component
Using the 'principle of equal dilution' it is possible to assess the toxicity of a mixture in terms of an equivalent concentration of a given toxic reference substance. A suitable reference substance for motor vehicle exhaust gas mixture is carbon monoxide. The equivalent concentration of carbon monoxide \( c_{CO} \) is estimated from the equation:

\[
c_{CO} = c_{CO}^{o} \sum_{i=1}^{Z} \frac{c_{i}}{c_{CO}^{o} c_{i}}
\]

where \( c_{CO}^{o} \) is the maximum permissible concentration for carbon monoxide

Using this method of expressing the toxicity of a gas mixture, it has been found possible to establish numerical indices of air pollution capacity of a motor vehicle or an internal combustion engine. Carcinogenic substances must be left out of consideration since it has been assumed that they have no threshold concentration.

The degree of air pollution does not depend only on the composition of the contaminating gas mixture but also on the amount discharged. Thus, in order to assess the air pollution capacity of an internal combustion engine both the equivalent carbon monoxide concentration and the volume of exhaust gases have to be estimated. The amount of exhaust gases depends on the driving conditions of the automobile and the adjustment of the engine. It is obvious that the air pollution capacity of an automobile will be proportional to the quantity \( q \) of toxic substances discharged per unit of useful work done. This quantity \( q \), expressed in terms of the equivalent amount of carbon monoxide, has been chosen as an index of the air polluting capacity of the engine and will be called 'specific air polluting capacity of the engine'. It may be estimated from the following equation:

\[
q = \frac{1}{N_{e}} \sum_{i=1}^{Z} \frac{c_{CO}^{o} G_{i}}{c_{i}} = \frac{G_{CO}}{N_{e}}
\]

where \( G_{i} \) = the amount of toxic substance \( i \) discharged per unit time (kg/h)

\( N_{e} \) = the effective power of the engine under given operating conditions (HP)

\( G_{CO} \) = the amount of all toxic substances discharged per unit time expressed in terms of the equivalent amount of carbon monoxide (kg/h)

The technological purpose of a motor vehicle is to carry goods, passengers or to propel itself over a certain distance, and therefore the 'specific air polluting capacity of the engine' has to be related to the distance covered by the vehicle. If this is done another index \( \tau_{a} \) is obtained which will be called 'the air polluting capacity of the automobile'. This index is defined by:

\[
\tau_{a} = \frac{G_{CO}}{v_{a}} \text{ kg/km}
\]

where \( v_{a} \) is the velocity of the automobile in km/h (\( G_{CO} \) has already been defined in the equation (3)). \( \tau_{a} \) is, in fact, the weight of toxic material discharged by the automobile per unit distance.

\[\text{In the USSR terminology this is the 'specific toxicity of the engine'.}\]
One important feature of these two indices (q and $\tau_a$) is that they enable us to assess objectively - from the point of view of air pollution - the design, construction and adjustment of an engine and an automobile under different operating or driving conditions. The numerical values of these indices depend, of course, on the driving conditions and the adjustment of the engine (engine variables), and the air polluting capacity of the engine or the automobile has to be assessed under standardized conditions (see Fig. 2).

Standards of air polluting capacity should be established for every type of automobile separately.

The determination of the air polluting capacity of an automobile should be carried out either under actual driving conditions or under conditions simulating the actual situations. The estimation of $\tau_a$ requires the knowledge of the composition of exhaust gases and their volume. Since it is very difficult to obtain these data under actual driving conditions, special testing stands have been constructed. The automobile is driven on a stand equipped with rolling drums, and the following variables are measured simultaneously: the load, the effective power of the engine, the fuel consumption, the output of exhaust gases, and the velocity of the automobile. The composition of exhaust gases is also determined. Since the exhaust gas output and the concentration of the pollutants vary to a large extent under different modes of engine operation, it is necessary to specify a standard driving cycle. The standard driving cycle in the United States of America (typical of driving conditions in Los Angeles) is different from standard driving cycles in Europe. Fig. 3 compares these two types of driving cycles. Experience in the USSR has shown that it is sufficient to estimate the air polluting capacity under three different driving conditions: cruising at 80 km/h; acceleration in direct transmission from the most stable speed up to 80 km/h; and idling.

It can be shown that the air polluting capacity of an automobile can be estimated approximately by using the following equation:

$$\tau_a = \frac{G_t}{v} \left(14.9 \alpha + 1\right) c^{co}$$

(5)

where 

- $G_t$ = fuel consumption per hour
- $\alpha$ = excess air coefficient
- $c^{co}$ = equivalent concentration of carbon monoxide

The value of $\alpha$ is easily estimated from the gas analysis data. For a petrol engine

$$\alpha = \frac{14.3}{c^{co} + c^{co2}} - 0.067$$

(6)

where $c^{co}$ and $c^{co2}$ are the concentration of carbon monoxide and carbon dioxide, respectively, expressed in volume per cent.

Thus, to estimate the air polluting capacity of an automobile, the concentration of the toxic (noxious) substances in the exhaust gases, the fuel consumption and the velocity of the automobile have to be measured.

The following equation is used in the USSR to express the concentration of toxic substances in terms of an equivalent concentration of carbon monoxide ($c^{co}$):
\[ c^{co} = c^{co} + 10c^{HCHO} + 10c^{NO} + 0.5c^{CH} \]  

(\(c^{CH}\) is the concentration of hydrocarbons). All concentrations in this equation should be expressed in mg/m\(^3\). The soot (carbon black) can be also taken into account by using a coefficient of 20.

Infra-red analyses are recommended for determination of carbon monoxide and carbon dioxide. Other components can be determined by chromatography. (The samples are taken by evacuated aspirators.) With proper organization, the whole testing procedure does not take more than six to ten minutes and it is feasible even when a very large number of automobiles has to be checked.

**BIBLIOGRAPHY**


3. Šešejkovskij, G. V. (1947) Smoke in towns, Moscow (In Russian)

4. Čudakov, E. A. (1961) Selected papers, Moscow (In Russian)


Fig. 1  Concentrations of toxic components of petrol engine exhausts vs. air-fuel ratio
Fig. 2  Specific air polluting capacity of the engine (q) vs. excess air coefficient for different spark advance angles (θ)
Fig. 3  Comparison of American and European driving cycles
Air Pollution by Metallurgical Plants and Methods of Control
SOME PROBLEMS OF AIR POLLUTION FROM FERROUS METALLURGY PLANTS

by

D. N. Kaljužnij

There are many different sources of air pollution in ferrous metallurgy plants. Some of them will be briefly discussed.

The basic raw materials in the production of iron and steel are iron ore, coke and fluxes. The preliminary treatment if iron ore includes crushing, screening, sizing, concentrating and agglomerating either by briquetting or sintering by partial fusion. Most of these operations produce dust.

Sintering machines are sources of dust, carbon monoxide and sulfur dioxide. According to 'GIPROMEZ' (State Institute for Design of Metallurgical Plants) technological effluents, ventilation air and uncontrolled effluents discharge into the atmosphere 29.2 kg of dust for each ton of agglomerate produced if dust collecting devices are not used; dust control reduces the discharge to about 2.3 kg/ton.

There are two main sources of air contamination in coke production: the coal preparation department and the coke ovens. If no air cleaning is applied, the mechanical and natural ventilation of the coal preparation plant discharges about 2.2 kg of dust for each ton of coke produced. The coke ovens contaminate the ambient air with dust, sulfur compounds, carbon monoxide and phenol; the emission occurs during charging, coking, unloading and quenching operations. The coke gas, the main by-product of coke plants, is collected and brought to a chemical plant where gas tar, benzene, naphtha and other commercial products are recovered. The cleaned gas is used as fuel. In all these operations some coke gas escapes into the atmosphere by leakage, mainly during the charging process; it has been estimated that this loss amounts to about 4-5 m$^3$ per ton of charge (1.2 to 1.5 per cent.). The nature of effluents from coke plant stacks depends on the fuel used for heating coke ovens. If blast furnace gas is utilized, large quantities of carbon monoxide may escape into the atmosphere. Sulfur dioxide is the principal pollutant discharged if heating is performed by coke gas, Chemical units of coke plants discharge various contaminants but in small quantities.

A by-product in the production of pig iron is blast furnace gas. It contains large amounts of suspended matter, carbon dioxide, sulfur dioxide and some other impurities in smaller concentrations. Since it contains a large fraction of the total heat input, the gas is recovered, cleaned and used as fuel in other departments of iron and steel works. Although the gas collecting and cleaning are highly efficient operations, the blast furnace is still an air pollution source. (A major problem in blast furnace operation is 'slips' when furnace burden shifts irregularly resulting in violent gas rush into the piping system. To prevent damage to the furnace relief valves permit the gas to escape into the atmosphere.) It has been estimated that a typical blast furnace releases about 300 kg of suspended matter and 10 000 kg of carbon monoxide daily.

The major part of steel is produced in the USSR by converter and open-hearth process. The converter represents one of the most difficult air pollution problems in the steel industry. It pollutes the atmosphere with dust, sulfur dioxide and carbon monoxide, particularly during the second part of the operation cycle, known as carbon blow. According to Marcinovskij and Pogrebinskij, 75 to 80 kg of hot (1500 to 1700°C) gas containing about 120 g/m$^3$ dust are discharged per ton of iron. The total amount of particulate matter (containing about 90 per cent. iron oxide) varies from 10 to 27 kg/ton of iron processed. A 250-ton converter ejects about 200 kg of sulfur dioxide daily. There is no effective method of confining effluent gases.
Flue gases from open-hearth furnaces contaminate the atmosphere by particulate matter and sulfur dioxide. Ventilation air from the working area is an additional pollution source. Oxygen-lanced open-hearth furnaces operate at a higher temperature which promotes the formation of iron oxide fumes. According to Medzibózsíkij the average dust load of open-hearth effluents amounts to 0.4 to 0.7 g/m³; in oxygen-lanced furnaces this is increased to 1.5 to 2.5 g/m³. The total discharge of solids amounts, on average, to about 1 to 2 kg/ton and 4 to 6 kg/ton, respectively.

The air quality in the vicinity of iron and steel works is influenced more by the emissions from maintenance and auxiliary plants (pig iron foundries, processing of sintering additives, fire-brick manufacture, steel ingot production, etc.) than by rolling mills which discharge negligible quantities of gas and dust.

A large amount of data on air pollution towns situated in the vicinity of iron and steel works has been accumulated by the Kiev Research Institute of General and Community Hygiene. This material gives a fairly good picture of the influence of ferrous metallurgy plants on ambient air quality and of its effects on the health of the exposed population.

The air pollution level was measured by estimating the concentration of suspended matter, sulfur dioxide, carbon monoxide, hydrogen sulfide and phenol - these contaminants being considered as typical. Air was sampled at different distances from the plant (900 m, 1, 2, 3, 4, 6, 8 and 10 km) taking into account the meteorological conditions.

The concentration of dust was found to be high; even at 6 km from the plant the concentration was twice as high as the maximum permissible concentration (both the single MPC and the 24-hour average MPC). Only at a distance of 8 km did the dust concentration fall below the MPC. It is interesting to note that the dust concentration has been increasing steadily during the past five years which is probably due both to an intensified production and to insufficiency of dust control measures. Dust concentrations found in the vicinity of iron and steel works are listed in the following table (Table 1).

<table>
<thead>
<tr>
<th>Distance from the plant</th>
<th>Concentration found *</th>
<th>Percentage of samples with dust concentration above the MPC</th>
<th>Multiples of MPC observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum</td>
<td>Daily average</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>11.74</td>
<td>3.28</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>6.49</td>
<td>1.23</td>
<td>86</td>
</tr>
<tr>
<td>4</td>
<td>4.89</td>
<td>1.05</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>1.04</td>
<td>0.38</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>0.71</td>
<td>0.15</td>
<td>27</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* After subtracting the windward concentration which is considered to be the background value.

A significant pollution of air by sulfur dioxide and hydrogen sulfide has also been established. At 4 km from the plant the highest concentrations of sulfur dioxide exceeded the MPC 2.5 times. At 6 km from the source the SO₂ concentrations were of the order of the MPC; only at a distance of 8 km was the contamination by sulfur dioxide found to be insignificant.
Hydrogen sulfide contamination extended up to 6 km from the plant. Only at 8 km did the H₂S concentration fall below the MPC. The results have been summarized in Table 2.

**TABLE 2. CONTAMINATION OF AIR BY SULFUR DIOXIDE AND HYDROGEN SULFIDE IN THE NEIGHBOURHOOD OF FERROUS METALLURGY PLANTS**

<table>
<thead>
<tr>
<th>Distance from the plant</th>
<th>Sulfur dioxide Max. conc. mg/m³</th>
<th>Mean conc. * mg/m³</th>
<th>Multiples of MPC observed</th>
<th>Hydrogen sulfide Max. conc. mg/m³</th>
<th>Mean conc. mg/m³</th>
<th>Multiples of MPC observed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.97</td>
<td>0.68</td>
<td>4.0</td>
<td>0.11</td>
<td>0.024</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>1.32</td>
<td>0.50</td>
<td>2.6</td>
<td>0.05</td>
<td>0.018</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>1.27</td>
<td>0.48</td>
<td>2.5</td>
<td>0.013</td>
<td>0.005</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>0.49</td>
<td>0.13</td>
<td>-</td>
<td>0.030</td>
<td>0.007</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>0.14</td>
<td>0.07</td>
<td>-</td>
<td>0.006</td>
<td>0.001</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* 24-hour average concentration.

It was also found that the carbon monoxide concentrations exceeded the maximum permissible concentrations at distances up to 1 km. At greater distances the concentration of CO decreased rapidly. However, the fact that carbon monoxide could be detected in the ambient air at a distance of 2 to 6 km indicates that under unfavourable meteorological conditions serious air pollution levels could be reached in residential areas situated near metallurgical plants. A better control of blast furnace emissions is definitely needed.

Quenching of coke by phenol containing waste waters releases phenol into the atmosphere. Phenol was found in ambient air up to 1 km (downwind) from coke plants.

Several authors investigated the effects on health of air pollution from metallurgical plants. A questionnaire study showed that the major part of complaints referred to eye injuries by dust, and coughing and headaches. A study of an adult population residing 4 km from a metallurgical combine revealed the prevalence of arterial hypotension, marked vascular instability and low spirometrical index. Significant amounts of carboxyhaemoglobin were found in a large number of subjects living near an iron and steel works. The Kiev Research Institute of General and Community Hygiene investigated 990 schoolchildren residing at different distances from ferrous metallurgical plants. Twice as many cases of upper respiratory tract disease were found among these children compared with a (control) group of children of the same age living in non-industrial districts.

Thus it seems that ambient air pollution from non-ferrous metallurgical plants may have an adverse effect on the health of an exposed population.

According to the present regulations in the USSR a sanitary protective zone of 1 km should be established around ferrous metallurgy plants. Results reported in this review show that this may not be sufficient for large metallurgical plants.
BIBLIOGRAPHY

1. Ministry of Health of the USSR, State Sanitary Inspection (1963) Methodological instructions for ambient air pollution investigations, Moscow, Medgiz (In Russian)

2. Kaljužnij, D. N. (1961) Protection of ambient air from pollution by effluents from iron and steel works, Kiev, Gosmedizdat (In Russian)


4. Saprickij, V. N. (1965) Air cleaning in metallurgy, Moscow, Metallurgia (In Russian)
Non-ferrous metallurgy is a potent source of air pollution. Roasting and smelting of ores and ore concentrates produce large amounts of metal fumes and dust which are carried away in effluent gases. The effluents also contain various other contaminants such as sulfur dioxide, sulfur trioxide, carbon monoxide, hydrogen chloride, chlorine, fluorine, etc. Emission of particulates (usually expressed as a weight percentage of the processed material) depends on many factors, the most important being the type of extraction unit, the metallurgical process used, and the physical and chemical properties of the raw material (grain size, mechanical properties, content of volatile metals and compounds, etc.). Fume and dust emission is particularly intense in some recently developed metallurgical operations such as fluidized bed roasting, suspension roasting and various fuming procedures (Waelz process, slag fuming). Some numerical values for the emission of particulates in different pyrometallurgical processes used in the production of copper, lead, zinc and nickel are presented in Table 1. Although not of general validity (emissions vary from plant to plant), these figures indicate how vitally important efficient dust and fume control systems are in non-ferrous metallurgical plants, not only from technological, and economic points of view, but also for those of health.

There are two approaches to the control of harmful emissions from non-ferrous metallurgical plants:

(a) appropriate modification of the technological process and plant design;

(b) application of efficient gas cleaning and dust removal methods.

A typical example of the first method as applied in the USSR is the use of an upward blast with recirculation instead of downward suction in sintering of lead concentrates. The upward blasting process yields gases with 5 to 6 per cent. $\text{SO}_2$ and they can be used for production of sulfuric acid. A discharge of tens of thousands of tons of sulfur is thus avoided every year. If sintering plants are operated with suction, the concentration of sulfur dioxide does not exceed one per cent.; conversion to sulfuric acid is uneconomic and gases are discharged into the atmosphere. According to the available data 23.9 per cent. of the total production of sulfuric acid in the USSR is based on utilization of metallurgical gases; by 1970 this will increase to 27.9 per cent.

All modern non-ferrous metallurgy plants in the USSR are equipped with dust-collecting installations which, in most cases, have a satisfactory capacity and efficiency. Because of large variations in composition and properties of gases (temperature, humidity) and of suspended matter (particle size, electrical properties), non-ferrous metallurgical plants apply many different kinds of dust control devices.

Gravity settling chambers were widely used for collecting coarse dust. They have now been replaced by various types of cyclones (dry and wet) which are cheaper, more efficient and less bulky. Scrubbers and foam gaswashers are even more efficient for coarse dust removal.

Fumes are removed more efficiently by electrical precipitators and sleeve-filters.
TABLE 1. EMISSION OF PARTICULATES IN DIFFERENT PYROMETALLURGICAL PROCESSES USED IN THE PRODUCTION OF COPPER, LEAD, ZINC AND NICKEL

<table>
<thead>
<tr>
<th>Pyrometallurgical process</th>
<th>Dust and fume emission as percentage of the charge</th>
<th>Weight per cent. of metal found in particulate form</th>
</tr>
</thead>
<tbody>
<tr>
<td>COPPER METALLURGY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple hearth roasting</td>
<td>5-15</td>
<td>Zn: 45, Pb: 24.5</td>
</tr>
<tr>
<td>Fluidized bed roasting</td>
<td>35-45</td>
<td></td>
</tr>
<tr>
<td>Blast furnace smelting (primary raw material)</td>
<td>2-8</td>
<td>Cu: 1.0-3.3</td>
</tr>
<tr>
<td>Blast furnace smelting (secondary raw material)</td>
<td>3-4</td>
<td></td>
</tr>
<tr>
<td>Converting (primary raw material)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Converting (secondary raw material)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LEAD METALLURGY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sintering</td>
<td>0.5-1</td>
<td>Pb: 2.1</td>
</tr>
<tr>
<td>Blast furnace smelting</td>
<td>3-5</td>
<td>Pb: 0.5-2</td>
</tr>
<tr>
<td>(faulty operation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hearth smelting</td>
<td>25-30</td>
<td>Pb: 15-20</td>
</tr>
<tr>
<td>Slag fuming</td>
<td></td>
<td>Pb: 95-97, Zn: 88-90</td>
</tr>
<tr>
<td>ZINC METALLURGY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluidized bed roasting</td>
<td>30-40</td>
<td>Zn: 92, Pb: 85, Cd: 97</td>
</tr>
<tr>
<td>NICKEL METALLURGY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfide ore roasting</td>
<td>8-10</td>
<td>Ni: 2-4</td>
</tr>
<tr>
<td>Blast furnace smelting (oxide ores)</td>
<td>7-16</td>
<td></td>
</tr>
<tr>
<td>Converting</td>
<td>2-2.5</td>
<td></td>
</tr>
</tbody>
</table>

Multipolar horizontal electro-filters are used extensively in Soviet non-ferrous metallurgical plants. The linear gas velocity is maintained at 0.5 m/s. Wet electro-filters are applied mainly in the final stage of purification before the gases are admitted to the contact process sulfuric acid production units. The collection efficiency of modern multipolar electro-filters with improved high voltage units amounts in many cases to 96 to 98 per cent. without any pre-treatment of gases; this has been observed even for dust with high electrical resistivity and for lead, zinc and their metal-oxide fumes.

Sleeve-filters are also widely applied in non-ferrous metallurgy. Their efficiency is very high (90 per cent. and more) and depends less on the physicochemical properties of suspended matter than does the efficiency of dry electro-filters. Availability of various synthetic 'nitron', 'lavsan' and glass fabrics, which have excellent thermal properties and are highly acid resistant, has greatly contributed to the widespread use of fabric-filtration methods in industrial gas cleaning. For example, woolen fabrics applied previously as filtration media could only be used for gas temperatures not exceeding 100°C; lavsan and nitron fabrics are usable up to 130 to 140°C and glass fabrics even at 220 to 250°C.

A comparatively recent development (since about 1950) in fume control is the Venturi-scrubber, but the use of turbulent scrubbers in non-ferrous metallurgy is limited by the corrosive properties of effluent gases and the resulting liquid waste disposal problems. The discharge into the atmosphere of cool acid gases produced by turbulent scrubbers presents additional problems.
In spite of the successful application of different dust-removal techniques the quality of ambient air in the vicinity of some non-ferrous metallurgy plants is not satisfactory. This is due partly to an intensified operation of extraction plants and to the rapidly growing concentration of industry in certain regions of the USSR, and also to insufficient cleaning (or no cleaning in most cases) of ventilation air before its discharge into the atmosphere. The concentration of noxious substances in ventilation air is usually low but volumes of air, and consequently the total mass of contaminants, are very large. For this reason many non-ferrous metallurgy plants have recently devoted much attention to the problem of ventilation air cleaning. The reverse jet filter has proved a suitable device for cleaning large volumes of gases; the filtration speed is five to seven times higher than in the ordinary sleeve or bag filters, and collection efficiency remains satisfactory (90 per cent. or more for highly disperse aerosols).

In large non-ferrous metallurgy plants in the USSR special dust control and ventilation services supervise the operation of gas cleaning installations and carry out air pollution surveys within the factory and in its vicinity. There is, of course, a close collaboration of dust control and ventilation services with the local sanitary authorities.

BIBLIOGRAPHY

1. Šejn, A. P. & Gudima, N. V. (1964) A short handbook of non-ferrous metallurgy, Moscow, Metallurgia (In Russian)

2. Loskutov, F. M. (1965) Metallurgy of lead, Moscow, Metallurgia (In Russian)

3. Šneerson, B. L. (1963) Electrical cleaning of gases, Moscow, Cvetmetizdat (In Russian)
SOURCES OF AIR POLLUTION AND CONTROL METHODS

Most of the crude (primary) aluminium produced today both in the USSR and abroad is obtained by electrolysis of alumina in molten cryolite (3 NaF·AlF₃). The electrolytic reduction cells have either lateral or top current connexions and self-baking anodes. Pre-baked anodes are also used. Reduction cells with lateral current supply are equipped with shutter blinds where gases and aerosols produced during electrolysis are exhausted. The highly efficient cells with top current supply have no shutters and waste gases are collected under the anode through a bell-shaped gas collector and removed to a combustion system.

The main contaminants emitted by the reduction cells are various resinous substances, hydrocarbons and fluorine compounds contained in the bath (cryolite, calcium fluoride, aluminium fluoride, sodium fluoride). The consumption of anode material amounts to about 600 kg per ton of aluminium. The anode material contains 20 to 30 per cent. of coal tar pitch with about 0.05 per cent. of 3,4-benzpyrene. Fluorine is consumed at a rate of 30 kg per ton of aluminium in reduction cells with lateral current supply; in cells with top current connexions it attains a rate of 60 to 70 kg/ton of aluminium.

Waste gases removed by the local exhaust system ("controlled effluents") are conducted to purification installations. The purification is effected in two stages: dry purification (electro-filtration) removes resinous substances and particulate fractions of fluorine compounds; hydrogen fluoride, produced by thermal decomposition of other fluorine compounds (the temperature in the electrolysis bath is about 1000°C), is retained by a wet purification system (scrubbers or foam screens). The collection efficiency of the purification system is about 80 per cent. for resinous substances and about 95 to 98 per cent. for fluorine compounds. The collected resinous material is burnt in special combustion devices; fluorine compounds are regenerated into cryolite and returned to the production cycle.

Leakage of waste gases into the working area cannot be prevented by the local exhaust system. These 'uncontrolled' effluents are discharged into the atmosphere by the general ventilation system of the working area without any purification. Purification of 'uncontrolled' effluents is a very difficult problem, particularly in winter months when the temperature of the surrounding ambient air is low. But it should be also pointed out that the purification of the general ventilation air before discharge would solve one part of the problem only; the other part, the contamination of working environment, still remains. The only satisfactory solution of this difficult question is to modify the design of high capacity cells with top current supply and improve their gas-withdrawal system in such a way as to minimize the leakage. A research programme with this objective has been initiated by the USSR Ministry of Non-Ferrous Metallurgy and is now in progress in the All-Union Institute for Aluminium and Magnesium.

The control of effluents from reduction cells with lateral current supply is a comparatively recent development. Some 10 years ago an almost generally accepted method of controlling effluents from medium capacity reduction cells was to discharge the waste gases through high stacks (about 120 m) directly into the atmosphere, assuming that the dilution by atmospheric diffusion would reduce the concentration of pollutants sufficiently. Monitoring of air pollution in the vicinity of an aluminium plant with a fairly high rate of anode consumption and no electro-filtration showed that this was indeed true for some contaminants. Thus, for example, the concentration of 3,4-benzpyrene in the windward direction varied from 0.51 to 0.69 µg/m³ which is a fairly low level. On the other hand, the concentrations of
fluorine compounds in the neighbourhood of the same factory amounted to 0.11 to 0.24 mg/m$^3$, although the daily discharge through the stack was comparatively small (3.0 to 3.5 tons). This example clearly shows that fluorine compounds are the most characteristic air contaminants from aluminium production. If the effluents are discharged through high stacks and the surrounding area is flat, a more or less uniform dispersion of fluorine compounds will occur through fairly large distances from the source (Fig. 1).

Similar measurements performed in the vicinity of a modern aluminium plant (reduction cells with top current supply, two stage purification of controlled effluents, discharged through an 80 m stack) showed that, already at 3 km from the source, the concentration of fluorine compounds was fairly low (probably caused by uncontrolled effluents).

**BIOLOGICAL EFFECTS OF FLUORINE AND THE MAXIMUM PERMISSIBLE CONCENTRATIONS**

Small quantities of fluorine are indispensable for normal development of many plants. In man and animals it promotes the synthesis of organic phosphorus compounds in soft tissues, facilitates the formation of bone mineral and improves the metabolism of calcium and phosphorus. Many clinical and experimental investigations have pointed out that fluorine promotes the ossification process and that it is necessary for normal function of the dental tissue. It also plays an active role in the biochemistry and physiology of various enzymes and hormone systems. The physiological optimum intake of fluorine for man is about 3 mg per day. Under normal conditions this amount is available in water and food.

Deficiency of fluorine causes osteoporosis, retards the formation of bone and contributes to the development of caries.

On the other hand, excessive intake of fluorine, particularly by inhalation, produces serious pathological changes. Concentrations of fluorine in ambient air of the order of 0.1 to 0.2 mg/m$^3$ may have undesirable effects on child population (increased incidence of respiratory diseases; appearance of mottled enamel). Fluorine gases are toxic to some plants in very small concentrations (<0.1 mg/m$^3$). Fluorine compounds absorbed from the air accumulate in soil and vegetation, and animals that graze in the vicinity of factories discharging fluorides into the air may develop fluorosis.

The following maximum permissible concentrations of fluorine and fluorine compounds in the air of inhabited areas have been established in the USSR:

<table>
<thead>
<tr>
<th>Substance</th>
<th>MPC at any time (mg/m$^3$)</th>
<th>Daily average MPC (mg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaseous fluorine compounds (HF, SiF$_4$)</td>
<td>0.02</td>
<td>0.005</td>
</tr>
<tr>
<td>Very soluble fluorine compounds (NaF, Na$_2$SiF$_6$)</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>Slightly soluble fluorine compounds (AlF$_3$, Na$_3$AlF$_6$, CaF$_2$)</td>
<td>0.2</td>
<td>0.03</td>
</tr>
</tbody>
</table>

In view of the fact that effluents from many plants (aluminium production, cryolite production) contain both gaseous fluorine and fluorine salts, research has been undertaken into the combined effect of fluorine-fluoride mixtures. Provisional MPCs for simultaneous air pollution by gaseous fluorine and fluorine compounds are 0.03 mg/m$^3$ (at any time) and 0.01 mg/m$^3$ (daily average).


7. Lukomskij, G. I. (1940) Fluorine in medicine, Moscow, Medgiz (In Russian)

8. Rappoport, A. (1949) Farmakol. i Toksikol, 12, 6


12. Sadilova, M. S. (1957) In: Maximum permissible concentrations of atmospheric pollutants, Moscow, Medgiz (In Russian)

13. Sadilova, M. S. (1967) In: Biological effects and hygienic significance of atmospheric pollutants, 10, Moscow, Medgiz (In Russian)
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Professor V. B. Vouk, WHO Consultant
(Rudjer Bošković Institute, Zagreb, Yugoslavia)
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>10.00-11.00</td>
<td>Opening of Seminar</td>
</tr>
<tr>
<td></td>
<td>Professor P. P. Ljarskij</td>
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<td></td>
<td>Mr R. Pavanello</td>
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<tr>
<td>11.00-11.30</td>
<td>Break</td>
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<tr>
<td>11.30-12.30</td>
<td>The organization and structure of the Sanitary-Epidemiological Service in the USSR</td>
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<tr>
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<td>Professor P. P. Ljarskij</td>
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<tr>
<td>12.30-13.10</td>
<td>The role and activity of the USSR Sanitary-Epidemiological Service in air pollution prevention</td>
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<tr>
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<td>Dr M. K. Nedogibčenko</td>
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<tr>
<td>13.10-14.30</td>
<td>Discussion</td>
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<tr>
<td>09.30-10.10</td>
<td>Air pollution control - the activities of WHO</td>
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<tr>
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<td>Mr R. Pavanello</td>
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<tr>
<td>10.10-10.50</td>
<td>WHO and criteria for air quality</td>
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<td>Professor V. B. Vouk</td>
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<td>10.50-11.10</td>
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<tr>
<td>11.10-11.50</td>
<td>Methods of determining the maximum permissible concentrations of atmospheric pollutants</td>
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<td>Dr C. A. Čičikov</td>
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<tr>
<td>11.50-12.50</td>
<td>Pollution of the ambient air by carcinogenic substances and cancer of the lung</td>
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<td>Professor L. M. Šabad</td>
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<tr>
<td>12.50-14.00</td>
<td>Discussion</td>
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<tr>
<td>09.30-10.10</td>
<td>Chronic bronchitis and air pollution</td>
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<td>Dr P. J. Lawther</td>
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<tr>
<td>10.10-11.20</td>
<td>The influence of meteorological factors on air pollution and calculation of the diffusion of atmospheric pollutants</td>
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<td>Professor M. E. Berljand</td>
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<tr>
<td>11.00-11.20</td>
<td>Break</td>
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<tr>
<td>11.20-15.00</td>
<td>Visit to the Moscow City Sanitary Epidemiological Station</td>
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<tr>
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<td>Dr V. V. Rodionov</td>
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<td>Dr K. V. Jakovleva</td>
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| Monday     | 4 September| 09.30-14.00| Visit to the A.N. Sysin Institute of General and Municipal Hygiene of the Academy of Medical Sciences of the USSR  
Dr G. I. Sidorenko and staff |
| Tuesday    | 5 September|            | Departure for Volgograd                                                          |
| Wednesday  | 6 September| 09.30-10.30| The activity of the Sanitary-Epidemiological Service of the Volgograd Oblast in the field of air pollution control  
Dr Z. K. Drozdova |
|            |            | 13.00-15.00| Study of the planning of the City of Volgograd                                   |
| Thursday   | 7 September| 09.30-14.00| Visit to new industrial areas of Volgograd. Inspection of the cleaning installations in a lamp-black factory |
| Friday     | 8 September| 09.30-15.00| Visit to the Volzhskij Hydro-Electric Power Plant. Study of the zoning and lay-out of the town of Volzhskij |
| Saturday   | 9 September| 09.30-11.00| Concluding discussion on the visit to Volgograd                                  
Departure for Moscow |
| Sunday     | 10 September|            | REST                                                                             |
| Monday     | 11 September| 09.30-10.10| The organization of ambient air pollution surveys  
Dr S. N. Kimina |
|            |            | 10.10-11.20| A review of some methods for determination of pollutants in ambient air  
Mrs M. D. Manita |
|            |            | 11.20-11.40| Break                                                                            |
|            |            | 11.40-13.00| Discussion                                                                       |
| Tuesday    | 12 September| 09.30-10.20| Current problems of establishing hygienic standards in the field of environmental health  
Professor V. A. Rjazanov  
(the paper will be introduced by Dr V. P. Melehina and opened to discussion) |
|            |            | 10.20-11.00| Methods of studying the effects of ambient air pollution on the population  
Professor M. S. Gol'dberg |
|            |            | 11.00-11.20| Break                                                                            |
|            |            | 11.20-11.50| Discussion                                                                       |
|            |            | 12.00-14.00| Visit to the Moscow Power Station No. 20                                          |
Wednesday 13 September
09.30-10.20 Control of utilization of industrial gas cleaning installations in the USSR
Mr V. V. Gagarinskij and Mr A. G. Smirnov
10.20-11.00 Purification of industrial effluent gases from suspended matter
Mr V. N. Uzov
11.00-11.20 Break
11.20-12.00 The chemical purification of effluent gases
Mrs N. P. Pitelina
12.00-12.40 Non-ferrous metallurgy plants as sources of air pollution and methods of control
Mr G. M. Gordon
12.40-14.00 Discussion

Thursday 14 September
09.00-15.00 Visit to the Semibratovo Branch of NIIOGAZ (Research Institute for Gas Cleaning)

Friday 15 September
09.30-10.20 The present state of the problem of control of air pollution by motor vehicles
Professor I. L. Var'avskij
10.20-11.00 Air pollution capacity of internal combustion engines and automobiles
Mr L. S. Zolotorevskij
11.00-11.20 Break
11.20-14.00 Visit to the Laboratory for the Prevention of Pollution from Internal Combustion Engines
Professor I. L. Var'avskij

Saturday 16 September
09.30-10.10 The burning of fossil fuels as a source of air pollution
Dr R. S. Gil'denskjol'd
10.10-11.00 Odour exposure and annoyance reactions from craft pulp operations
Professor Lars T. Friberg
11.00-11.20 Break
11.20-12.00 The aluminium industry as a source of air pollution
Dr M. S. Sadilova
12.00-14.00 Discussion

Sunday 17 September
REST
<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>09.30-10.10</td>
<td>Some problems of air pollution from ferrous metallurgy plants</td>
</tr>
<tr>
<td>18 September</td>
<td></td>
<td>Professor D. N. Kaljužnij</td>
</tr>
<tr>
<td></td>
<td>10.10-10.30</td>
<td>Discussion</td>
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<td>10.30-11.00</td>
<td>Break</td>
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<tr>
<td></td>
<td>11.00-14.00</td>
<td>Discussion (Exchange of information on air pollution control programmed in different countries)</td>
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<tr>
<td>Tuesday</td>
<td>09.30-17.00</td>
<td>Visit to the city of Klin - a study of the operation of devices for removing mercury</td>
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<td>19 September</td>
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<tr>
<td>Wednesday</td>
<td>09.30-10.30</td>
<td>Answers to written questions</td>
</tr>
<tr>
<td>20 September</td>
<td>10.30-11.00</td>
<td>Concluding discussion and discussion of the draft report</td>
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<tr>
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<td>11.00-11.20</td>
<td>Break</td>
</tr>
<tr>
<td></td>
<td>11.20</td>
<td>Closure of the Seminar</td>
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</table>
1. The ambient air quality standards in the USSR are established by the Ministry of Health of the USSR and this authority is not delegated to any other administrative body. Air quality standards have legal power and are uniform throughout the USSR. Different ministries and organizations are consulted before a standard is adopted, but the Ministry of Health is the only authority to set such standards.

2. In the USSR there are two indices of the degree of air pollution - the maximum permissible concentration at a given time and the maximum permissible daily (24 hour) average concentration. The maximum permissible concentration at a given time is a standard of air quality set to prevent such pollution of the ambient air that may cause reflexes by irritating the receptors of the organs of breathing, mainly the olfactory area of the nose. The purpose of the daily average maximum permissible concentration is to prevent chronic resorptive effects of toxic substances. Both indices belong to the class of 'hygienic' standards which are the only ones recognized and adopted in the USSR. The maximum permissible concentrations are such concentrations of ambient air pollutants that do not directly or indirectly exert harmful or unpleasant effects on man, reducing his working capacity, or having a negative effect on his physical or mental well-being.

3. The following criteria are used in establishing ambient air quality standards in the USSR (V. A. Rjazanov (1965) Bull. Wld Hlth Org., 32, 389):

   Twenty-four hour average maximum permissible concentrations are based on tests carried out on experimental animals (changes in higher nervous activity, cholinesterase activity, excretion of coproporphyrin, changes in albumen fraction of the bloodstream). Tests on human volunteers provide a basis for determining the maximum permissible concentration at a given time. Methods used are: determination of odour threshold; pneumography, vasorheography, optical chronaxy, adaptation of visual organs to darkness, electrocortical conditioned reflex method using electroencephalography (alpha rhythm assimilation observations). It should also be pointed out that the maximum permissible concentrations are set up with respect to the most sensitive subject in a group.

4. There are no 'sanitary' or 'emission' standards for air pollution in the USSR.
### Maximum Permissible Concentrations of Pollutants in the Ambient Air (1967)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Maximum permissible concentrations in mg/m³</th>
<th>Maximum at any time</th>
<th>24-hour average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Acetaldehyde</td>
<td>0.01</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2. Acetic acid</td>
<td>0.2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>3. Acetic anhydride</td>
<td>0.1</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>4. Acetone</td>
<td>0.35</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>5. Acetophenone</td>
<td>0.003</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>6. Acrolein</td>
<td>0.3</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>7. Ammonia (NH₃)</td>
<td>0.20</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>8. Amy lacetate</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>9. Amylene</td>
<td>1.5</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>10. Aniline</td>
<td>0.05</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>11. Arsenic</td>
<td>-</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>12. Benzene (benzol)</td>
<td>1.5</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>13. Benzene, from crude oil (with low S content) as C</td>
<td>5.0</td>
<td>1.5</td>
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<tr>
<td>14. Benzene, from slate (as C)</td>
<td>0.05</td>
<td>0.05</td>
<td></td>
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<tr>
<td>15. Butane</td>
<td>200</td>
<td>-</td>
<td></td>
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<tr>
<td>16. &quot;Butiphos&quot; (Butifos) Tributyl-triphosphate</td>
<td>0.01</td>
<td>-</td>
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<tr>
<td>17. Butyl acetate (n-Butyl acetate)</td>
<td>0.10</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>18. n-Butyl alcohol</td>
<td>0.3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>19. Butylene (Butene-1)</td>
<td>3.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>20. Butyric acid</td>
<td>0.015</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>21. Caprolactum (vapour, aerosols)</td>
<td>0.06</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>22. Caprylic acid</td>
<td>0.01</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>23. Carbon disulfide</td>
<td>0.03</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>24. Carbon monoxide</td>
<td>3.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>25. Carbon tetrachloride</td>
<td>4.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>26. &quot;Carbophos&quot; (Karbofos) synonym Malathion</td>
<td>0.015</td>
<td>-</td>
<td></td>
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<tr>
<td>27. Chlorine</td>
<td>0.10</td>
<td>0.03</td>
<td></td>
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<tr>
<td>28. p-Chloroaniline</td>
<td>0.04</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Substance</td>
<td>Maximum permissible concentrations in mg/m$^3$</td>
<td>24-hour average</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum at any time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substances</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. Chlorobenzene</td>
<td>0.10</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>30. m-Chlorophenyl isocyanate</td>
<td>0.005</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>31. p-Chlorophenyl isocyanate</td>
<td>0.0015</td>
<td>0.0015</td>
<td></td>
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<tr>
<td>32. Chloroprene</td>
<td>0.10</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>33. Chromium, hexavalent</td>
<td>0.0015</td>
<td>0.0015</td>
<td></td>
</tr>
<tr>
<td>34. Cyclohexanol</td>
<td>0.06</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>35. Cyclohexanone</td>
<td>0.04</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>36. Dichloroethane</td>
<td>3.0</td>
<td>1.0</td>
<td></td>
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<tr>
<td>37. 2,3-Dichloro-1,4-naphthoquinone</td>
<td>0.05</td>
<td>0.05</td>
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<tr>
<td>38. Dicthylamine</td>
<td>0.05</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>39. Diketene</td>
<td>0.007</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>40. Dimethylaniline</td>
<td>0.0055</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(N,N-Dimethylaniline)</td>
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<td></td>
<td></td>
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<tr>
<td>41. Dimethyl disulphide</td>
<td>0.7</td>
<td>-</td>
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<tr>
<td>42. Dimethylformamide</td>
<td>0.03</td>
<td>0.03</td>
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<tr>
<td>43. Dimethyl sulfide</td>
<td>0.08</td>
<td>-</td>
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<tr>
<td>44. &quot;Dinil&quot; (24% of diphenyl + 76% Diphenyl oxide)</td>
<td>0.01</td>
<td>0.01</td>
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<tr>
<td>45. Divinyl</td>
<td>3.0</td>
<td>1.0</td>
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<tr>
<td>46. Dust, inert (non-toxic)</td>
<td>0.5</td>
<td>0.15</td>
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<tr>
<td>47. Epichlorhydrin</td>
<td>0.2</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>48. Ethanol</td>
<td>5.0</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>49. Ethyl acetate</td>
<td>0.1</td>
<td>0.1</td>
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</tr>
<tr>
<td>50. Ethylene</td>
<td>3.0</td>
<td>3.0</td>
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</tr>
<tr>
<td>51. Ethylene oxide</td>
<td>0.3</td>
<td>0.03</td>
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<tr>
<td>52. Fluorine compounds (as F)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gaseous compounds (HF, SiF$_4$)</td>
<td>0.02</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>v. soluble inorganic compounds (NaF)</td>
<td>0.03</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>s. insoluble inorganic compounds (AlF$_3$, Na$_3$AlF$_6$, CaF$_2$)</td>
<td>0.2</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>in mixture with gaseous F</td>
<td>0.03</td>
<td>0.01</td>
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</table>
### Maximum Permissible Concentrations of Pollutants in the Ambient Air (1967) (continued)

<table>
<thead>
<tr>
<th>Substance</th>
<th>Maximum permissible concentrations in mg/m³</th>
<th>Maximum at any time</th>
<th>24-hour average</th>
</tr>
</thead>
<tbody>
<tr>
<td>53. Formaldehyde</td>
<td>0.035</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>54. Furfural</td>
<td>0.05</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>55. Hexamethylenediamine</td>
<td>0.01</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>56. Hydrochloric acid as HCl</td>
<td>0.2</td>
<td>-</td>
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</tr>
<tr>
<td></td>
<td>0.006</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td>57. Hydrogen sulfide</td>
<td>0.008</td>
<td>0.008</td>
<td></td>
</tr>
<tr>
<td>58. Isopropyl benzene</td>
<td>0.014</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>59. Isopropyl benzene hydroperoxide</td>
<td>0.007</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>60. Lead and lead compounds (except tetraethyl lead) as Pb</td>
<td>-</td>
<td>0.0007</td>
<td></td>
</tr>
<tr>
<td>61. Lead sulphide</td>
<td>-</td>
<td>0.0017</td>
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</tr>
<tr>
<td>62. Maleic anhydride (vapour, aerosols)</td>
<td>0.2</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>63. Manganese and manganese compounds (as MnO₂)</td>
<td>-</td>
<td>0.01</td>
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<tr>
<td>64. Mercury, metallic</td>
<td>-</td>
<td>0.0003</td>
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<tr>
<td>65. Mesidine (2-amino-1,3,5-trimethyl benzene)</td>
<td>0.003</td>
<td>-</td>
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<td>66. &quot;Metaphos&quot; (Metafos) synonym Methylparathion</td>
<td>0.008</td>
<td>-</td>
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<tr>
<td>67. Methanol</td>
<td>1.0</td>
<td>0.5</td>
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<tr>
<td>68. Methyl acetate</td>
<td>0.07</td>
<td>0.07</td>
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<tr>
<td>69. Methyl acrilate</td>
<td>0.01</td>
<td>-</td>
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</tr>
<tr>
<td>70. Methylaniline</td>
<td>0.04</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>71. Methyl mercaptan</td>
<td>9.10⁻⁶</td>
<td>-</td>
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<tr>
<td>72. Methyl metacrylate</td>
<td>0.1</td>
<td>0.1</td>
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<tr>
<td>73. alpha-Methylstyrene</td>
<td>0.04</td>
<td>0.04</td>
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<tr>
<td>74. alpha-Naphthoquinone</td>
<td>0.005</td>
<td>0.003</td>
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<tr>
<td>75. Nitric Acid (as HNO₃)</td>
<td>0.4</td>
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<tr>
<td></td>
<td>0.006</td>
<td>0.006</td>
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<tr>
<td>76. Nitrobenzene</td>
<td>0.008</td>
<td>0.008</td>
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</tr>
<tr>
<td>Substance</td>
<td>Maximum permissible concentrations in mg/m³</td>
<td></td>
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<td>-----------------------------------------------</td>
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<tr>
<td></td>
<td>Maximum at any time</td>
<td></td>
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<tr>
<td></td>
<td>24-hour average</td>
<td></td>
<td></td>
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<tr>
<td>77. Nitrogen dioxide</td>
<td>0.085</td>
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<tr>
<td>$\text{NO}_2$</td>
<td>0.085</td>
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<tr>
<td>78. N-Pentane</td>
<td>100.0</td>
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<td></td>
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<tr>
<td></td>
<td>25.0</td>
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<tr>
<td>79. Phenol</td>
<td>0.01</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td></td>
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<tr>
<td>80. Phosphorus pentoxide</td>
<td>0.15</td>
<td></td>
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<tr>
<td></td>
<td>0.05</td>
<td></td>
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<tr>
<td>81. N-Propyl alcohol</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>82. Phthalic anhydride (vapour, aerosols)</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>83. Propylene</td>
<td>3.0</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>84. Pyridine</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.08</td>
<td></td>
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<tr>
<td>85. Soot</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.05</td>
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</tr>
<tr>
<td>86. Sulfuric acid as $\text{H}_2\text{SO}_4$</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>as $\text{H}^+$</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.006</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>0.006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>87. Sulfur dioxide</td>
<td>0.5</td>
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<td></td>
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<tr>
<td></td>
<td>0.15</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>0.05²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>88. Styrene</td>
<td>0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>89. Thiophene</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
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</tr>
<tr>
<td>90. Toluene</td>
<td>0.6</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>91. Toluylene di-isocyanate $\text{CH}_3\text{C}_6\text{H}_3(\text{NCO})_2$</td>
<td>0.05</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>0.02</td>
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</tr>
<tr>
<td>92. Trichloroethylene</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td></td>
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<tr>
<td>93. N-Valeric acid</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>94. Vanadium pentoxide</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>95. Vinyl acetate</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>96. Xylene (Xylol)</td>
<td>0.2</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>0.2</td>
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</tbody>
</table>
Notes:

1. If several substances with additive toxic properties are present in the air, the maximum permissible concentration (MPC) of the mixture is calculated from the following formula:

   \[ X = \frac{A}{M_1} + \frac{B}{M_2} + \frac{C}{M_3} \]  

   where \( X \) is the (relative) MPC; \( A, B, C \) are the concentrations of the substances in the mixture, and \( M_1, M_2, M_3 \) their respective maximum permissible concentrations.

2. If formula (1) is applied to the following two, three or four component systems, the value \( X \):

   should not exceed 1.0 for
   a. acetone and phenol
   b. \( \text{SO}_2 \) and phenol
   c. \( \text{SO}_2 \) and \( \text{NO}_2 \)
   d. \( \text{SO}_2 \) and HF
   e. \( \text{SO}_2 \) and sulfuric acid aerosol
   f. \( \text{H}_2\text{S} \) and "Dinil"
   g. isopropyl benzene and isopropyl benzene hydroperoxide
   h. furfural, methanol and ethanol
   i. strong mineral acids (sulfuric, hydrochloric and nitric, concentrations expressed \( \text{H}^+ \))
   j. ethylene, propylene butylene and amylene

   should not exceed 1.3 for
   a. acetic acid and acetic anhydride

   should not exceed 1.5 for
   a. acetone and acetophenone
   b. benzene and acetophenone
   c. phenol and acetophenone

3. If:

   a. \( \text{H}_2\text{S} \) and \( \text{CS}_2 \)
   b. CO and \( \text{SO}_2 \)
   c. phthalic anhydride, maleic anhydride and alpha-naphthoquinone

   are present in the mixture, the MPC values of individual substances should not be exceeded.
4. If para-chlorophenyl-isocyanate is present together with meta-chlorophenyl-isocyanate the MPC is determined by the presence of the more toxic substance, i.e. of para-chlorophenyl-isocyanate.

5. This list replaces the list of maximum permissible concentration of noxious substances in air of 26 December 1966, No. 655-66.
THE A.N. SYSIN INSTITUTE OF GENERAL AND MUNICIPAL HYGIENE

The A.N. Sysin Institute of General and Municipal Hygiene is one of the research institutes of the Division of Hygiene, Microbiology and Epidemiology of the USSR Academy of Medical Sciences.

The main objective of the Institute is to study the effects of various environmental factors on the health of the population. The current research projects are concerned with the effects of new synthetic chemicals, aerosols, electromagnetic radiation, microclimatic conditions; with scientific foundations of hygienic standards for environmental factors; and with applied research related to the improvement of hygienic and sanitary conditions in the USSR in general.

As the leading USSR institute in the field of general and municipal hygiene, the A.N. Sysin Institute coordinates all research in the USSR on biological activity and hygienic significance of environmental factors. It prepares and distributes general research programmes in this field to the medical research councils of the ministries of health of the constituent republics, and reviews and appraises the work carried out in other similar research institutes in the USSR. The A.N. Sysin Institute is the coordinating body for such research for all the countries included in the Council for Mutual Economic Cooperation (CONECOM). It is also one of the collaborating institutes of the World Health Organization.

The Institute also promotes practical application of research results. To this end it publishes a series of monographs, methodological manuals, etc. The Institute prepares methodological instructions and drafts of hygienic standards, and advises the Ministry of Health of the USSR on all problems of general and municipal hygiene. It also provides an advisory service to the sanitary-epidemiological stations and other organizations of the USSR Sanitary-Epidemiological Service.

The Institute offers training and research fellowships in the field of general and municipal hygiene and organizes scientific conferences, symposia and seminars. It takes part in the health education of the public by organizing lectures, publishing popular works on hygiene, etc.

The total staff of the Institute numbers about 250 persons (about 100 with academic qualifications).

The Institute has the following organizational units: Division of Air Hygiene, Division of Water Hygiene and Sanitary Protection of Water Bodies, Division of Soil Hygiene, Division for Studies of Microclimatic Conditions and Radiant Energy, Physiological Laboratory, Laboratory of Physico-Chemical Methods, Biochemical Laboratory, Laboratory for Radiochemical Research Methods, Laboratory for Sanitary Bacteriology and Virology, Laboratory for Pathomorphology, Electron Microscope Laboratory, Laboratory for New Synthetic Chemicals and Sanitary Toxicology, Division for Research Planning and Division of Consultation. Auxiliary units of the Institute include the Library and the Animal House.

Based on a lecture delivered by Dr G. I. Sidorenko, Director of the Institute.
The Director of the Institute is assisted by a Scientific Advisory Council which includes a number of senior staff as well as some external members (prominent specialists from institutes of hygiene and chairs of hygiene of Moscow Medical Institute).

Current research projects of the Institute in the field of air hygiene can be divided into the following five groups:


Three groups of substances are being studied: a carbon disulfide, benzene, phenol and ammonia; b m-nitro-chlorobenzene and 3,4-dichloro-aniline; c methylaniline and dimethylaniline. The purpose of the project is to elucidate the effect of chemical constitution on toxic properties of small concentrations of these compounds. The investigations comprise comparative studies of reflex activity of the human organism and resorptive effects in chronic experiments on laboratory animals.

2. Hygienic assessment of air pollution caused by discharges from certain chemical plants. The effects of air pollution on living conditions and health of the population. Development of protective measures.

This is a joint project of the Sysin Institute and the Institute for Hygiene, Sanitation and Occupational Diseases of the Uzbek SSR. The study is concerned with the so-called 'hydrolytic' industries (e.g. production of furfural) in the Uzbek SSR and the production of acetic acid and acetic acid anhydride.

3. Biological effects of small concentrations of chemical substances in air as a criterion for the establishment of the maximum permissible concentrations in the ambient air.

The objective of this project is the study of biological effects of certain new chemicals widely used in chemical industry (p-chloroaniline, metacrylate, tetrahydrofuran) as well as some components of motor vehicle exhausts in order to establish hygienic standards (MPCs for ambient air).

4. Carcinogenesis and atmospheric pollution.

Experimental studies of blastoma inducing activity of 3,4-benzpyrene. White rats are used as experimental animals, and the carcinogenic agent is administered intratracheally to animals under chronic exposure to sulfur dioxide. Four control groups are being followed simultaneously (exposed to 3,4-benzpyrene only, to sulfur dioxide, to the solvent for 3,4-benzpyrene and to air, respectively). Apart from pathomorphological examinations, this study includes biochemical investigations concerned with the mechanism of the effect of 3,4-benzpyrene on the oxidative and energy metabolism (aerobic and anaerobic glycolysis in certain tissues and changes in thiamine content in some organs).

5. Chemical reactions in the atmosphere and the formation of new toxic compounds. The biological activity and hygienic significance of such compounds.

This project comprises two topics: a formation of oxidants by photochemical reactions, and b hygienic appraisal of urban air pollution by photo-oxidation products. Mass-spectrometric and gas-chromatographic methods for quantitative determination of photo-oxidation products are being developed. Long-term studies on the content of photochemical oxidants in the atmosphere of large cities are planned, as well as experimental investigations of the reflex and resorptive effects of certain products of photochemical oxidation (ozone, oxides of nitrogen).