# CONTROL OF AIR POLLUTION IN THE USSR

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# INTRODUCTION

The fight for clean air in centres of population is a major problem in many countries of the modern world.

Up to the middle of the twentieth century the main source of air pollution was the combustion of mineral fuels in domestic grates and stoves, industrial enterprises, power stations, steam locomotives, etc., and the sulfur oxides, ash, and soot which they discharged were considered to be the main pollutants. However, the position in a number of countries has now begun to change, for the reduction in the sulfur content of fuel, the substitution of natural gas for solid fuels, the electrification of technological processes in industry, the installation of ash-collectors, and other measures are helping to solve the smoke problem in practice, not merely in theory. Nevertheless, with the rapid development of all types of industry (particularly the atomic power and chemical industries) and with urbanization, whereby large centres of population with endless streams of motor traffic are created and towns are built chaotically without rational planning, the urban atmosphere continues to be polluted with highly toxic substances harmful to the population's health.

The acute effects on public health of exposure to atmospheric pollution were noted when thick fogs occurred in London during the late nineteenth century. Toxic fogs in London have also occurred as recently as 1948, 1952, 1956, 1959, and 1962, causing deaths among members of the population particularly sensitive to atmospheric pollutants.

A study of overall mortality in the city of New York in the period 1962-1964 revealed 5 periodic mortality peaks caused by a high degree of atmospheric pollution combined with temperature inversion.

Increased morbidity as a result of fogs, temperature inversion, and industrial pollution of the atmosphere occurred in the Meuse Valley (Belgium) in 1930, at Donora (USA) in 1948, and at Posa-Rica (Mexico) in 1950, to give only a few examples. A serious warning and reminder of the need to fight for clean air is the increase noted in a number of countries in recent years in the incidence of chronic diseases of the upper respiratory tract, primarily bronchitis and emphysema, and of allergies such as asthma. It is also generally acknowledged that air pollution is an important causal factor in human lung cancer. Epidemiological data show that the frequency of lung cancer is continuously increasing in towns as compared with rural localities, a fact that cannot be ascribed solely to differences in the prevalence of the smoking habit.

The recurrent photochemical air pollution in Los Angeles, which irritates the mucous linings of the eyes, nose, and throat, is connected with the saturation of the urban atmosphere with organic substances discharged from motor-vehicle exhausts. Similar air pollution has been found to occur in San Francisco, Washington, New York, and towns in Italy, Japan, Australia, and elsewhere. The growth of motor transport throughout the world means that the danger of harmful exposure to these emissions is constantly increasing.

The WHO Expert Committee on Human Genetics has emphasized that such environmental factors as ionizing radiation and atmospheric pollution may increase the frequency of mutations.[1] A large number of the most diverse chemical substances and compounds have been proved to exert a mutagenic effect. Most of these organic compounds have not been studied from a toxicological and physiological point of view, and no data are available on the transformations they may undergo in the air, their combined effects, or their possible carcinogenic and teratogenic effects.

The threat to the health of human beings, plants, and animals, the reduced visibility in towns, and the corrosion and spoilage of buildings are all making air-pollution control a matter of urgent necessity. If control is to be effective, not only in arresting present atmospheric pollution but in preventing it in the future, it needs to be based on legislation. Standards of air purity must be established, for it is essential to know what degree of purity must be insisted upon. There is also a need for technical appliances, apparatus, and staff; in many countries sufficient knowledge and practical experience of air-pollution control has been built up, but the resources and staff allocated to clean up the urban air are still inadequate. Further efforts and international coordination of air-pollution control are needed, with a view not only to combating existing pollution but also to preventing further and possibly still more harmful effects of pollution on the health and wellbeing of the community.

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[1] *Wld Hlth Org. techn. Rep. Ser.*, 1964, No. 282.

The present work describes the experience in air-pollution control of the USSR, which was the first country in the world to lay down maximum permissible concentrations for atmospheric pollutants, and the co-operation between the countries belonging to the Council for Mutual Economic Assistance (CMEA) in regard to the problem of ensuring clean air. The approaches adopted in the USSR and the other countries of the CMEA to solve the air-pollution problem may also prove acceptable and useful to other governments.

*Chapter 1*

# THE DEVELOPMENT AND PRESENT STATUS OF AIR POLLUTION CONTROL IN THE USSR

## THE PERIOD BEFORE THE OCTOBER REVOLUTION, 1917

Before the Revolution, Russia, despite its immense natural and human resources, was a socially and economically backward country. For the main forms of industrial activity, its production per head of population was 13–14 times less than in the USA, 11–12 times less than in the United Kingdom, and 10 times less than in Germany. It smelted a little over 4 million tons of pig iron a year and roughly the same amount of steel, produced about 10 million tons of crude oil and about 7 million tons of coal, while the installed capacity of all its electrical power stations was only one million kilowatts. Most machines and equipment were imported from abroad. The population, particularly in the outlying areas, was almost completely illiterate.

Russia also lagged behind the rest of Europe in sanitary and medical matters. Constant epidemics and high rates of morbidity and mortality were a direct result of the social and economic backwardness of the country. The State took practically no interest in the provision of medical care for the population. Responsibility for public health lay with the Ministry of Internal Affairs, for which it was a matter of secondary importance. It is not surprising, therefore, that in 1913 overall mortality in Russia was 29.1 per thousand inhabitants, or double that of the other countries in Europe. Infant mortality was 269.6 per thousand births, 3–4 times as high as in the rest of Europe.

Tsarist Russia, with its backward economy, paid no more attention to the problem of air-pollution control than to other harmful environmental factors.

With the development of capitalism in Russia, partly with the foreign capital that had penetrated the country, the natural riches of Russia were plundered, industrial establishments were sited in a completely unplanned manner, and no interest was shown in protecting the environment from pollution. In some industrial towns the haphazard siting of residential districts among factories and mills, with the resultant smoky atmosphere and air pollution, made living conditions extremely unfavourable. However, no measures were taken to prevent air pollution, although the Medical Statutes in force at that time laid down that "the police must ensure that in or near the streets and on or near the roads and bridges, there shall be nothing that might infect the air". Another article in the same Statutes stipulated that "the building of factories, manufacturing establishments, mills, etc., with a detrimental effect on the purity of the air or water must conform to the special regulations set forth in the Industrial and Building Statutes". The Building Statutes stated that "no factories or mills with a detrimental effect on the purity of the air shall be built in towns or on rivers and tributaries upstream from towns". However, all these regulations remained mere pious wishes, usually ignored in practice.

In 1833 a decree was published on "the sanctioning and building of private factories, manufacturing establishments, mills and other establishments in St Petersburg". In this decree a first attempt was made to classify industrial enterprises on the basis of the harm they caused (pollution of water, air, etc.). They were divided into three categories and those in the third category could not be sited inside the town (Kaljužnyj, 1961). However, in the face of private capitalism this decree could not be carried out, any more than could other recommendations for the protection of the environment in the towns of Russia. In issue after issue, the Russian medical press and newspapers such as *Iskra* and *Zvezda* described the extremely harmful conditions under which people had to live and work in the industrial areas of Central Russia: Ivanovo-Voznesensk, Orehovo-Zuevo, Bogorodsk, etc. In the more remote areas of the country matters were still worse. Unsanitary living conditions in St Petersburg were the subject of numerous articles in *Zvezda* (1910), *Novaja Zvezda* (1912), etc.

Russian scientists and social workers were well aware of the harmful consequences of pollution of the air, water, and soil. F. F. Erisman,[1] in his lectures on hygiene to students at Moscow University in 1882, pointed out that "only after a whole range of experimental work did the general conviction take root that to preserve our health it was necessary to remove all foreign substances from the air as far as possible. Numerous morbid anatomical observations and statistical surveys were required to establish the effect that air contaminated with solid dust particles and pollutant gases produces on the major organs of the human

[1] Erisman's lectures are reproduced in volume 1 of his *Selected works* [*Izbrannye proizvedenija*] published by Medgiz, Moscow, in 1959.

body, such as lungs, eyes, nervous system, etc.". However, such statements by leading scientific hygienists in Russia did not result in practical measures to control air pollution. The ever worsening sanitary conditions in the country and the primitive nature of the medical services provided for the public caused serious alarm among progressive medical men, social workers, and statesmen. Various government commissions were set up to study living conditions in industrial areas, working conditions in particular factories and mills, etc. On the initiative of an eminent Russian physician, S. P. Botkin, an attempt was made in 1865 to set up a government commission to work out a tentative plan for establishing healthier conditions in centres of population in Russia. All these commissions, however, proved ineffective.

To Russian medical men at that time, the effect of the environment on the human organism and the need for active campaigns to prevent social diseases were completely beyond dispute. It had obviously become necessary to establish in Russia a specific organization to study morbidity and the effect of environmental factors on the health of the population. A. V. Petrov, who was Professor of Pathology at Kazan University, wrote in 1873: "After a thousand years of fruitless service to individuals, medicine and doctors are now called upon to serve society as a whole. We need to treat social diseases, to raise the level of public health, and to increase public wellbeing. Different approaches are needed and these will be effective only if the capacities of the population itself are also brought into play" (Veber, 1968).

In 1875, in a work entitled *The medico-statistical basis for the establishment of sanitation centres*, P. A. Peskov stated that the main task of such centres should be to study the effect on human health "of man's whole environment, in the sense both of the purely natural properties of the locality concerned and of the artificial living and working conditions produced by man himself" (Veber, 1968). This same period saw the establishment of the first posts for sanitarians[1] and the first laboratories of sanitation and hygiene. In 1891 the first urban sanitation centre was established at the Institute of Hygiene of Moscow University. It concerned itself with the examination of foodstuffs, drinking-water, sewage, soil, and air. The sanitation centres and sanitation commissions that had been set up earlier by a number of governments in Russia, and were later transformed into government sanitation councils, formed the basis for the Sanitation Organization that took shape in Russia during the last decade of the nineteenth century. The Sanitation Organization, with the support of progressive public opinion, submitted to the urban

[1] The word "sanitarian" is used in this paper to denote a fully-qualfied specialist, trained at university level (e.g., in a faculty of sanitation and hygiene at a medical school).

authorities and the central government a number of proposals designed to improve living and working conditions for the people. As a result of its insistent demands, the authorities took some steps to clean up centres of population, to improve water-supply and sewerage systems, etc. However, no great progress was made in solving the cardinal problems of improving the human environment. The country had no health legislation. The first attempts to control atmospheric pollution in Russia on the basis of legislation were made in 1913, when a bill for the "Control of Air, Water, and Soil Pollution" was introduced in the State duma by the Chief Medical Inspector's Department in the Ministry of Internal Affairs, together with draft "Regulations for the Protection of the Air against Smoke Pollution". However, neither the bill nor the regulations were adopted.

A. N. Sysin, an outstanding Soviet scientist and an eminent theoretician and practitioner in sanitation, discussing the unsatisfactory condition of sanitation in the pre-revolutionary era, wrote: "The whole past history of sanitation in Russia can be outlined in terms of three negative factors: the absence of a strong and authoritative central sanitation authority; the absence of nation-wide sanitary and health legislation; and the absence of local sanitary authorities organized on a planned and universal basis" (Barsukov, 1967).

## THE PERIOD AFTER THE OCTOBER REVOLUTION

In the very first days of the existence of the Soviet State serious attention began to be paid to the problem of environmental health. A start was made on the establishment of a sanitary service when the country was suffering from a serious economic situation, famine, and destruction. In June 1918 the first All-Russian Congress of Medico-sanitary Departments was held in Moscow; it adopted a resolution on centralizing the management of sanitation, establishing a special sanitary inspectorate, making sanitary services more easily accessible to the population, and enlisting the help of the public on a wide scale in carrying out sanitation and health measures.

On 18 June 1918 the People's Commissariat of Health of the Russian Soviet Federal Socialist Republic (RSFSR), headed by N. A. Semashko, was established by government decree. The basic principles of the Soviet health services and of all legislative acts to protect public health took shape under the guidance of Lenin, who signed over 100 decrees on various aspects of public health. These decrees defined State responsibility for the public health services in the new social order and outlined measures for dealing with the main theoretical problems relating to this important sphere of State activity.

The programme adopted at the Eighth Congress of the Russian Communist Party in 1919 stated:

The Party bases its activities to protect the health of the population primarily on carrying out extensive health and sanitation measures aimed at preventing the development of disease. In view of this the Party sets as its next task a vigorous programme of extensive sanitary measures in the interests of the working people, which will include :

1. (*a*) the cleaning-up of the urban environment and the protection of the soil, water, and air from pollution;
   (*b*) the establishment of public catering on a hygienic basis;
   (*c*) the organization of measures to prevent the development and spread of communicable diseases;
   (*d*) the drafting of health legislation.

2. A campaign against social diseases: tuberculosis, venereal diseases, alcoholism, etc.

3. The provision, free of charge, of universally available curative and preventive services of a high standard.

The Party's programme set forth the main principles of the Soviet health services, and protection of the health of the people was for the first time given State recognition in a socialist State. Great significance was attached to protecting the environment on a nationwide scale, and relevant decrees were issued in almost all the Union Republics between 1922 and 1926. The restoration of the national economy after the Civil War required a well organized network of sanitary and epidemiological establishments and a system of State sanitary surveillance. On the initiative of the Gomel Department of Sanitation and Epidemiology, the first sanitary and epidemiological centre was established on 29 October 1922. It was the prototype of the standard combined sanitary and epidemiological establishment representing all the main elements required in sanitation and the control of epidemics, including laboratories. Later, similar establishments began to be set up in many parts of the country.

In 1931 the sanitary and epidemiological centres were given permanent and independent status, and in the following year it was decided to set up such centres everywhere as the main establishments in the sanitary and epidemiological service. By the end of 1940 there were 1958 centres in the USSR, with a staff of 11 121 sanitary physicians [1] and other university-trained specialists. In 1935 an All-Union State Sanitary Inspectorate was set up by the Soviet of People's Commissars of the USSR, one of its main tasks being to co-ordinate the work of the sanitary inspectorates throughout the USSR.

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[1] Medical education in the USSR is specialized, and students are trained for careers in general practice, paediatrics, or public health and hygiene. The sanitary and epidemiological services are staffed mainly by physicians specializing in public health and hygiene, who are referred to in this publication as sanitary physicians.

The industrialization of the Soviet Union and the construction of the first workers' settlements, which began after the Revolution, made it necessary to draft health rules for the planning and building of centres of population. As long ago as 1920, a decree was issued by the People's Commissariat of Labour on the protection of centres of population from the harmful effects of industry. Under that decree special areas were set aside for the construction of industrial undertakings, as part of the general plan covering building in centres of population.

The need for healthier conditions in urban districts and for the control of air, water, and soil pollution played a major role in the development of hygiene research and made it essential for experts in scientific hygiene to participate in the development of the national economy. In 1921 the Moscow Institute of Hygiene (F. F. Erisman Institute) was set up, and 1923 saw the establishment of the Institute for the Study of Occupational Diseases, now the Institute of Work Hygiene and Occupational Diseases of the Academy of Medical Sciences of the USSR. In 1929-1930 the first research on the prevention of atmospheric pollution began in the USSR. Its aim was to obtain scientifically based information on the degree and nature of atmospheric pollution resulting from the planning and reconstruction of towns, the erection of new building and industrial plants, etc. For that reason Soviet scientists, in contrast to their colleagues in other countries, directed their efforts not to determining total air pollution but to establishing the part played by individual sources of pollution and studying their zonal distribution, with a view to devising ways of reducing as far as possible the harmful effect of industrial pollutants on the population in the surrounding districts. Naturally, the attention of hygienists was focused in the first place on the most important sources of air pollution. Their investigations covered a number of large industrial centres, including Moscow, Leningrad, and centres in the Ukraine and the Urals. The results of their research were used in drawing up the first elements of health legislation on the siting of industrial undertakings and the principles underlying the establishment of health-protection zones between residential areas and such undertakings. Another important line of research was the development of methods of sampling and examining aerosols, and particularly the discovery of scientific reasons for changing over from sedimentation methods to aspiration methods, which make it possible to determine the concentration of pollutants per unit volume of air.

During these years, much was done to encourage research and promote the practical control of air pollution by the publication of a number of handbooks and instruction manuals on methods for the study of the environment and the atmosphere in particular. Thus, V. A. Rjazanov

(1934) described and assessed various methods for the study of dusts, including methods of determining their physical and chemical properties, composition, and biological effects. A. I. Burštejn (1934) reviewed methods for the study of aerosols, described methods for the bacteriological investigation of material suspended in the air and of dust that had settled out of it, and presented a plan for standardizing research methods. V. A. Uglov (1934), in his book *The control of dust, smoke and gases in population centres*, not only gave methods for measuring dust and smoke in the atmosphere but also described the techniques used for measuring gaseous atmospheric pollutants such as chlorine, sulfur dioxide, carbon monoxide, arsenic, ammonia, and hydrocarbons. The book also covers control measures such as town planning, the selection of industrial sites, construction standards, the improvement of heating systems, and air cleansing procedures.

This period also saw the start of research on atmospheric pollution from industrial wastes. The work of L. G. Lejtes, N. G. Poležaev & S. A. Pliseckaja (1936), among others, is an example of the types of investigation carried out.

A considerable contribution to the protection of the atmosphere and to the control of air pollution in industrial premises was made by N. V. Lazarev & P. I. Astrahancev in their major work on *Harmful industrial chemicals* (1933-35). This provided the sanitary services with a carefully compiled work of reference on the doses, compositions, and effects of the chemicals to which people were exposed, both occupationally and generally. Data were included on the effects produced by specific doses of harmful substances on experimental animals.

The toxicology of various chemical compounds was widely covered in the literature of the time—an example being the manual by N. S. Pravdin (1934)—although the amount of research done on the effect of air pollution on human health remained small.

In April 1935, the first All-Union Conference on Air Pollution Control was held at Kharkov. It was attended by only eight institutes and laboratories of hygiene. The following topics were among those discussed:

— clean air in towns
— methods of studing the air
— organization of sanitary surveillance for air pollution control
— legislation for the protection of air quality in populated areas
— research done on air pollution control up to 1935.

By the time the Second Conference on Air Pollution Control was held, in April 1938, the number of institutes and laboratories presenting papers had risen to 26. Data on pollution of the air by dust, soot, and various mixtures of gases were discussed. The papers read stressed the need to prepare recommendations on maximum permissible concentrations, on the sensitivity of air sampling methods, and on standard research methods.

During 1935-36, a special corps of urban sanitary inspectors with responsibility for air pollution control was established in a number of cities.

The development of motor transport also made it necessary to study the problem of increased pollution of the air in the towns by exhaust gases. Investigations on atmospheric pollution by motor exhaust fumes began in 1938 at the All-Union Institute of Community Sanitation and Hygiene of the People's Commissariat of Health of the USSR, and the first results were reported at an All-Union Conference on Atmospheric Pollution in the same year. Such conferences had been convened regularly since 1935.

Parallel with the development of scientific research and the extension of institutes of hygiene, technical organizations also began intensive efforts to find the most rational techniques of gas scrubbing, dust separation, and ash trapping and to design the appropriate apparatus. One such organization, established in the 1920s, is known as *Gazoočistka* (gas purification) and is concerned with the mechanical, chemical, and electrical cleansing of industrial gases. It has an institute for research on the industrial and sanitary cleansing of gases (NIIOGaz) and an institute for the design of gas purification installations and apparatus (*Giprogazoočistka*). As a result of the successful solution of the technical aspects of gas purification and dust separation, a special industry producing gas cleansing apparatus has grown up in the USSR.

A "master plan for the reconstruction of the city of Moscow" adopted by the Soviet Government in 1935 was an important landmark in the development of town planning in the USSR. It served as a guide for the design, reconstruction, and planning not only of Moscow but of other old towns. The recommendations for a lower building density in residential districts and for raising the standards of hygiene, insolation, and ventilation became the basis for town planning regulations. The principle of providing green spaces and planting vegetation in towns and of ensuring a wide belt of forest and parks, as was done round Moscow, became standard practice for town planning in the USSR. In April 1937 the Soviet of People's Commissars of the USSR issued a further decree concerning the fitting of smoke-abatement devices in the electric power stations of Moscow.

Air-pollution control in towns developed rapidly in the USSR after the Revolution in connexion with the industrialization of the country, the reconstruction of old towns and industrial centres, and the building of new socialist towns and industrial centres. This development was slowed down during the Second World War.

The years following the Second World War were extremely difficult for the country as a whole and for the sanitation and epidemiological service in particular.

The invading forces had wreaked an immense amount of damage; 1710 towns and settlements and over 70 000 villages and hamlets were destroyed and burned, 32 000 industrial enterprises were razed to the ground, plants responsible before the war for 60% of the country's steel production were wrecked, and pits that had provided over 60% of the nation's coal were destroyed. Over 25 million persons were left without a roof over their heads. The evacuation of this vast population from the occupied areas and their subsequent return to the ruined cities created unbelievable difficulties in maintaining environmental conditions of even minimal standard (water supply, waste disposal, etc.).

Remedying the health consequences of the war was one of the main tasks of the Government through those years. The restoration and further development of industry and modern agricultural production and the growth of towns and workers' settlements meant that constant attention had to be paid to problems of environmental health, and particularly air-pollution control. In order to control pollution of the atmosphere with ash, gases, and other harmful substances, to eliminate losses of ferrous and non-ferrous metals and valuable chemical products, and to improve conditions of sanitation and hygiene in centres of population, the Council of Ministers of the USSR adopted a resolution in 1949 prohibiting the acceptance of building, reconstruction or rehabilitation projects for industrial enterprises, individual workshops, power stations, and central heat-and-power stations discharging ash, unburnt coal, soot, and dust into the atmosphere, unless the designs provided for appropriate installations to separate ash and dust. Building plans for other industrial establishments were subjected to similar restrictions: non-ferrous metal plants had to possess devices to trap dust, sulfur compounds, nitrogen arsenide, and fluorine compounds; coke by-product plants had to possess installations to trap hydrogen sulfide and sulfur dioxide; iron and steel works had to have facilities for the removal of particulate matter from blast-furnace gases, so that the gases could be used for fuel; and industrial undertakings using solvents had to have installations for recuperation of the solvents. The resolution instructed ministries and other government bodies to forbid the operation of new enterprises, individual workshops, or units discharging harmful gases, fumes, and dust into the atmosphere unless provision was made for the cleansing of their emissions. It was stipulated that the operation of new and rebuilt enterprises, workshops, and units that polluted the atmosphere could be authorized only by the State Sanitary Inspectorate of the USSR. The resolution also pointed to the need to organize and carry out research in a number of institutes on gas purification, the separation and recuperation of dust, the training of staff, and the design of laboratory equipment and apparatus to measure atmospheric pollution. The protection of the air in towns and industrial districts from contamination with industrial waste and effluent became a compulsory feature of the work of the State Sanitary Inspectorate.

An important event in the development of Soviet health legislation, particularly in regard to the planning and building of residential areas and the control of air pollution in such areas, was the issue in 1947 of an All-Union State Standard, under which industrial enterprises were divided into 5 classes on the basis of the hazards they represented and the technological processes they used. The width of the health protection zones around such establishments was laid down as follows:[1]

| | |
|---|---|
| Class I — 2000 m | Class IV — 300 m |
| Class II — 1000 m | Class V — 100 m |
| Class III — 500 m | |

The State Sanitary Inspectorate was authorized to promote an establishment to a higher class if the effect of industrial pollution on the population was reduced or eliminated.

An important milestone in the further development of the campaign for clean air in the USSR was the Twefth All-Union Congress of Experts in Hygiene, Epidemiology, Microbiology, and Communicable Diseases, held in Moscow from 13 to 20 October 1947. The Congress noted shortcomings in the organization of the sanitary and epidemiological services in the USSR and underlined the lack of co-ordination between the work of sanitarians, State sanitary inspectors, and epidemiologists. It was pointed out that the work of the sanitation organization consisted predominantly in routine sanitary surveillance, which often assumed extremely primitive forms. Sanitarians and epidemiologists had not become real organizers of wide-ranging sanitary and health measures. One of the essential shortcomings in the research work of hygienists and in the practical activities of the sanitary and epidemiological authorities was that the importance of sanitary engineering was overestimated. While fully recognizing the importance of engineering in the organization of sanitary measures, the Congress stressed the cardinal role of research and practice designed to improve the health status of the population.

[1] On 5 November 1971, the State Committee on Construction of the Council of Ministers of the USSR approved the "Sanitary design standards for industrial establishments, No. 245-71", which revised the health classes assigned to industrial establishments and set new widths for the health protection zones as follows: Class I–1000 m; Class II–500 m; Class III–300 m; Class IV–100 m; Class V–50 m.

In his work the sanitarian should be in close contact with therapeutic, preventive, and other medical establishments. Special emphasis was placed on the danger of hygienists and practical workers in sanitary and epidemiological centres failing to pay sufficient attention to the physiology and pathology of man. A statement made over half a century before by F. F. Erisman had a very modern ring: "The separation of hygiene from its starting-point—the human body—and the breaking of its organic links with medicine would be an extremely dangerous operation, which might have a regrettable effect on the further development of our knowledge of hygiene."

In the discussion that developed at and after the Congress it was contended that, in hygiene research, environmental factors should be considered only from the point of view of their effect on the human body and on the health of the population. This trend, tentatively called the "physiological hygiene" trend, won general acceptance, and a new stage began in the development of Soviet air-pollution control: hygienists began to conduct complex research on the interactions between the human body and its environment by making a thorough study of the changes occurring in the organism following exposure to atmospheric pollution of differing intensity and duration.

Research on the biological effect of atmospheric pollution in the USSR took three main directions: experimental research on the maximum permissible content of harmful substances in the urban air, by studying under laboratory conditions the effect of these substances in given concentrations on the human and animal organism; direct research on the body's reaction to exposure to atmospheric pollution under natural conditions, by studying the effect of toxic substances in the atmosphere on human health and by carrying out biological experiments under natural conditions; and comparative study of morbidity statistics in industrial areas with a polluted atmosphere and in control areas.

In 1948 the Council of Ministers of the USSR issued a decree concerning measures to control air pollution in the city of Moscow. This instructed the Ministry of Health of the USSR, as a matter of urgency, to work out standards for maximum permissible concentrations of harmful substances in the atmosphere in urban areas. An *ad hoc* committee, set up under the leadership of Professor V. A. Rjazanov at the Moscow Institute for Research on Hygiene (the F. F. Erisman Institute), carried out extensive work to provide a scientific basis for these standards. First of all, on the basis of an analysis and summary of toxicological research, clinical statistics, etc., the committee worked out standards for maximum permissible concentrations of the 10 substances most frequently encountered in the air of towns: sulfur dioxide, hydrogen sulfide, carbon bisulfide, carbon monoxide, nitrogen oxides, chlorine, mercury, lead, dust, and soot. These standards were tried out in practice by a special Inter-institute Standardization Committee under the chairmanship of Professor A. N. Sysin, set up on the instructions of the Sanitary Inspectorate of the Ministry of Health of the USSR. They were confirmed by the Chief Sanitarian of the USSR on 1 August 1951 as indicators for sanitary evaluation of the purity of the air in urban areas, and thereby became the world's first standards for air purity. At the same time, methods for the qualitative and quantitative determination of sulfur dioxide, carbon bisulfide, chlorine, hydrogen sulfide, carbon monoxide, dust, and soot in the atmosphere were approved (Rjazanov, 1952a).

The Department of Community Sanitation at the Central Institute for Advanced Medical Studies became a centre for research on scientific methods of setting hygienic standards in regard to atmospheric pollution. It was there that the foundations were laid of methods to establish an experimental basis for maximum permissible concentrations of atmospheric pollutants (Rjazanov et al., 1957).

One aspect of research on hygiene that developed considerably in the post-war period was the study of the effect of atmospheric pollution on the living conditions and health of the population. Work of this kind was first carried out by M. S. Gol'dberg at the Institute of General and Community Sanitation of the Academy of Medical Sciences of the USSR. In a study of air pollution with fumes from thermal power stations, combined with mass clinical and X-ray examinations of children twice in a period of 3½ years, he showed that exposure to quartz-containing aerosols could have a detrimental effect on children's health (Gol'dberg, 1958). These data were later confirmed by Janyševa (1957) and others. Kaljužnyj (1959) found that industrial emissions from metallurgical plants unfavourably affected the health of the population within a radius of 3 km of the plants. Research to determine the effect on public health of phosphorite dust established that there is a correlation, revealed by X-ray examination, between the extent of the dust burden in the atmosphere and respiratory disease among the population, even in adults who are not occupationally exposed but have lived constantly in a dust-laden atmosphere (Peršin, 1952). Wherever this type of investigation was carried out, results indicated the possibility of penetration into the body from the polluted atmosphere of lead, mercury, phenol, fluorine, sulfur dioxide, chloroprene, and other components of industrial emissions, and higher morbidity indices were found among children in areas with a polluted atmosphere than in control areas. Particularly striking were the results of research carried out on groups of children to study changes in their state of health that were connected with a specific pollutant: for example, mottled dental enamel was found in children exposed to industrial emissions containing fluorine compounds (Sadilova, 1957), and signs of hypotension, leukopenia, and thrombocytopenia (i.e., signs of the specific effect of hydrocarbons) were observed in children exposed to pollution from the petrochemical industry (Krasovickaja et al., 1965).

A. A. Šmakov (1957) studied the effect of asbestos dust on children's health, and found that controls, from districts with clean air, put on weight faster and were less prone to acute catarrh of the upper respiratory tract than were children living in districts exposed to emissions from asbestos dressing plants.

Z. Ja. Lindberg (1960), in a study of the effect of emissions from a superphosphate works on the health of people living in the vicinity, found that exposure to high concentrations of sulfur dioxide, fluorine compounds, sulfuric acid mist, and nitric oxide increased morbidity among children and adults by a factor of 1.6–5.7 over that for people living in districts with clean air. This increased morbidity was manifested in children by higher incidences of the following conditions: catarrh of the upper respiratory tract, enlargement of the lymph glands, changes in the bone structure (scoliosis, residual rheumatism), and tuberculosis. Overall morbidity among adults was increased by a factor of 1.6–2.6, and the factors by which particular conditions were increased were as follows: diseases of the ears, nose, and throat 2.1–4.9; sore throats 2.0–4.1; diseases of the respiratory tract 3.0–5.3; tuberculosis 4.6–5.7.

D. N. Kaljužnyj (1959), in an attempt to determine the effect of industrial emissions on human health, made an analysis of the air in two industrial towns with large metallurgical works and two control towns which had no industrial enterprises. In all these towns a mass clinical and radiological examination was carried out on children between the ages of 8 and 14 years.

Figures showing the extent to which the air in these towns was polluted by dust and sulfur trioxide are given in Table 1.

TABLE 1. AIR POLLUTION IN INDUSTRIAL AND NON-INDUSTRIAL TOWNS

| Town | Concentration (mg/m³) | | | | | |
|---|---|---|---|---|---|---|
| | Dust | | | Sulfur trioxide | | |
| | Max. | Min. | Mean | Max. | Min. | Mean |
| 1 | 6.00 | 0.24 | 1.81 | 0.80 | 0.1 | 0.25 |
| 2 | 4.83 | 0.7 | 2.06 | 0.91 | 0.19 | 0.52 |
| 3 (control) | 0.35 | 0.1 | 0.21 | 0.05 | 0 | 0.05 |
| 4 (control) | 0.37 | 0.14 | 0.25 | 0.27 | 0.01 | 0.05 |

The results of the study showed that the maximum dust content of the air in the industrial towns was 4.83 mg/m$^3$ and 6.00 mg/m$^3$ (the latter figure being over the maximum permissible concentration). At the same time, the controls gave maximum dust content values of only 0.35 mg/m$^3$. In the industrial towns the atmospheric dust contained up to 15% of free silicon dioxide. Within a radius of 2–3 km of the metallurgical works, high concentrations of sulfur compounds were also found.

A clinical and radiological examination was carried out on all children in Town No. 1 living in factory residential quarters within 6 km of the metallurgical works. Town No. 3 (20 km away) served as the control. The examination was carried out on 630 schoolchildren with negative Pirquet and Mantoux tests and who had been living in the town concerned for not less than 3 years.

A second series of examinations was carried out in Town No. 2, in the district in which the metallurgical works was located, and in Town No. 4, the control. In all, 355 children were examined.

The results of radiological examination of the children are given in Table 2.

TABLE 2. GROUPING OF CHILDREN IN INDUSTRIAL AND NON-INDUSTRIAL TOWNS ACCORDING TO SEVERITY OF LUNG CONDITIONS

| Town | Groups I+II | | Groups III+IV | | Total |
|---|---|---|---|---|---|
| | No. | % | No. | % | |
| 1 | 365 | 68.6 | 167 | 31.4 | 532 |
| 2 | 124 | 73.0 | 46 | 27.0 | 170 |
| 3 (control) | 78 | 81.7 | 20 | 18.3 | 98 |
| 4 (control) | 177 | 95.7 | 8 [a] | 4.3 [a] | 185 |

[a] Group III only, as no children were found in Group IV.

For greater clarity, the children examined were divided into groups. Group I consisted of normal children, Group II of those showing minor changes limited to the roots of the lungs, Group III of those with pronounced changes in the lungs, and Group IV of those with extremely severe pathological changes in the lungs. In practice, Groups I and II were considered jointly, as were Groups II and IV.

Study of the radiograms showed that, of the children examined in the industrial towns, 68.6% and 73.0% respectively belonged to Groups I and II, while the percentages for the two non-industrial towns were 81.7% and 95.7%.

On the other hand, 31.4% and 27.0% of children in the industrial towns belonged to Groups III and IV while the percentage in Town No.3 (control) was 18.3%. In Town No. 4 (control), only 4.3% of the children examined were in Group III and there were none at all in Group IV.

The comparison thus indicates that the lungs of children living in the smoke-laden air near large metallurgical factories are in worse condition than the lungs of children of the same age living in towns where the air is free from industrial smoke.

T. S. Egorova (1967) studied the effect on children's health of air polluted with silicon dioxide dust. The air in the vicinity of a plant producing silicon and silicon alloys showed a relatively high degree of pollution from aerosols of condensed silicon dioxide. Air samples were collected, in summer, over an area 3 km in radius, and in each case the overall dust content, the free silicon dioxide concentration, and the percentage of silicon dioxide in the dust were determined.

As Table 3 shows, the highest concentration of dust (4.1 mg/m$^3$) was found on the factory premises. Outside, i.e., beyond 300 m of

TABLE 3. DUST CONTENT OF THE AIR AT VARIOUS DISTANCES FROM A SILICON ALLOY WORKS

| Distance from source of air pollution (km) | No. of samples | Mean concentration of dust in samples collected (mg/m$^3$) | Proportion of samples in which dust content exceeded maximum permissible concentration of 0.5 mg/m$^3$ (%) |
|---|---|---|---|
| on premises | 23 | 4.1 | |
| 0.3 | 25 | 3.1 | 100 |
| 0.5 | 25 | 2.5 | 100 |
| 1.0 | 26 | 2.0 | 100 |
| 2.0 | 24 | 1.8 | 100 |
| 3.0 | 25 | 3.0 | 100 |

the plant and within a radius of 3 km, the dust content was in the range 2–3 mg/m$^3$. The zonal distribution of the free silicon dioxide followed the same pattern as that for the dust content (Table 4).

TABLE 4. FREE SILICON DIOXIDE IN AIRBORNE DUST AT VARIOUS DISTANCES FROM A SILICON ALLOY WORKS

| Distance from source of air pollution (km) | No. of samples | Proportion of samples in which free silicon dioxide was found (%) | Mean concentration of free silicon dioxide ($mg/m^3$) | Proportion of free silicon dioxide in the dust (%) | |
|---|---|---|---|---|---|
| | | | | mean | max. |
| on premises | 23 | 100 | 0.72 | 14.0 | 41.6 |
| 0.3 | 25 | 100 | 0.54 | 16.0 | 36.0 |
| 0.5 | 25 | 88 | 0.30 | 11.2 | 31.5 |
| 1.0 | 24 | 83 | 0.37 | 20.0 | 66.0 |
| 2.0 | 24 | 87.5 | 0.19 | 11.8 | 32.0 |
| 3.0 | 25 | 92 | 0.50 | 14.7 | 45.0 |

A simultaneous study was made of the effect of the industrial emission on the health of children living 0.2–1.0 km from the works. For purposes of comparison, a district with relatively clean air, situated 6 km from the plant, was selected as a control.

The effects of industrial emissions were assessed by statistical analysis of child morbidity data obtained from the records of first attendances at children's advisory clinics, from clinical examination records, from physical development records, and from a survey carried out among the population on the effect of the emissions on the general conditions of life and health. The study and control groups had similar standards of living and enjoyed the same level of medical care.

The morbidity data obtained from the records of first attendances at children's advisory clinics were broken down according to age for the whole age range covered by the clinic's register, use being also made of physical development records, in which all notes on the health of the children examined are kept in chronological order.

Comparison of the data for the two districts revealed a higher overall morbidity among children living in the area subject to pollution. Thus, overall morbidity among children in their first year of life was 37% higher in the district with dust-laden air than in the control district. Among 1-year-olds it was 27% higher, among 2-year-olds 30% higher, among children aged 3-6 years 16% higher, and among children aged 7-14 years 45% higher. Diseases of the ear, nose and throat (generally catarrh of the upper respiratory tract) were particularly prevalent among children in the district with dust-laden air. Statistical analysis of the child morbidity data from the records of first attendances at children's advisory clinics enabled the incidence of infections of the respiratory organs and of the ear, nose and throat to be determined with a high degree of reliability (Table 5).

TABLE 5. CHILD MORBIDITY DATA IN DISTRICTS WITH DUST-LADEN AND DUST-FREE AIR
(Number of cases of disease for every 1000 children examined)

| Overall morbidity | Diseases of the respiratory organs | Diseases of the ear, nose, and throat | Communic-able diseases | Diseases of the digestive organs | Other diseases |
|---|---|---|---|---|---|
| Control district | | | | | |
| 107.5 ±0.63 | 15.35 ±0.80 | 37.7 ±1.00 | 45.90 ±1.10 | 4.29 ±0.45 | 3.98 ±0.43 |
| District with dust-laden air | | | | | |
| 132.2 ±2.49 | 21.92 ±1.40 | 54.60 ±1.69 | 51.00 ±1.70 | 4.57 ±0.70 | 6.41 ±0.83 |
| Significance test | | | | | |
| 12 | 4.1 | 8.5 | 2.5 | 0.33 | 2.4 |

Data from children's medical examinations also revealed a higher incidence of diseases of the respiratory organs (especially the ear, nose and throat) among children living in the district with dust-laden air. Thus, 18% of children in that area were found to have chronic otitis and tonsillitis, whereas only 7.8% of children in the control district had these diseases. Chest radiography and blood tests showed no special differences to exist between the children from the two districts.

Study of the physical development of children involved measurement of height, weight, and chest volume. The physical data for each child examined were compared with the standard measurements for the age and sex and the child classed as average, below average, or above average. In the industrial district, 24% of boys and 29% of girls examined were below average, while in the control district the respective figures were 9% and 10.3%.

This study shows that industrial pollution of the air has a harmful effect on children's health, causing an increase in overall morbidity (affecting primarily the respiratory organs and the ear, nose and throat) and retarding physical development.

The above are only a small selection of the very many studies that have been carried out on the effect of atmospheric pollution on human health.

Biological experiments were also carried out under natural conditions to study the effect of atmospheric pollutants on the organism. Thus, Tomson (1959), Hačatrjan (1955) and others studied the accumulation of lead in experimental animals (white rats, rabbits) exposed for

3–5 months at various distances (ranging from 300 m to 40 km) from industrial sources of atmospheric pollution with lead.

In his early work on the absorption of lead by the body on exposure to small concentrations of the metal in the air, N. M. Tomson (1952) kept white rats for 5 months in polluted air at a distance of 300 m from the source of pollution—a plant for processing non-ferrous metal wastes. The air where the experimental animals were kept was found to contain up to 0.02 mg/m³ of lead. The lead content of the bodies of the experimental animals was determined by spectrum analysis of the ashes of various tissues and organs and compared with that for the controls, which had been kept in clean air outside the town (Table 6).

TABLE 6. LEAD CONTENT IN FRESH TISSUE OF RATS EXPOSED TO LEAD-CONTAMINATED AIR FOR 5 MONTHS, COMPARED WITH THAT IN CONTROLS

| | Lead content (mg/100 g) | |
|---|---|---|
| | Controls | Experimental animals |
| bone | 1.21 | 9.55 |
| liver | 0.87 | 2.30 |
| skin | 0.18 | 1.36 |
| muscle | 0.08 | 1.23 |
| lungs | 0.12 | 1.15 |
| testicles | 0.09 | 0.75 |
| heart | 0.06 | 0.70 |
| brain | 0.06 | 0.68 |

The table clearly shows that lead had accumulated in the organs of animals exposed to air with a lead content of 0.02 mg/m³. Subsequently, these findings were confirmed by A. S. Zykova (1957), who studied cats that had lived for 2–7 years at a distance of 100–200 metres from a tin-smelting plant. By performing serial spectrograms of lead in the bone, tissues, and organs both of the exposed animals and of a control animal that had lived under clean atmospheric conditions, the author established that lead accumulates in the organism in proportion to the duration of exposure and to the concentration of lead in the atmosphere.

The highest concentration of lead was found in the bones. As Table 7 shows, the amount of lead in the bones was directly related to the length of time spent by the animal in the lead polluted atmosphere. The amount of lead found in the tibias and femurs of animals exposed to emissions containing the metal was 6 to 100 times higher than that found in the control cat.

TABLE 7. LEAD CONTENT OF THE TISSUES OF CATS

| | Age of cat (years) | Lead content mg/kg | | | | |
|---|---|---|---|---|---|---|
| | | tibia | femur | brain | kidneys | liver |
| Exposed cats | | | | | | |
| A | 2 | 120 | 200 | 300 | 65 | 175 |
| B | 3 | 180 | 260 | 400 | 125 | 90 |
| C | 4 | 1000 | 880 | 140 | 120 | — |
| D | 7 | 2000 | 1640 | 200 | 70 | 150 |
| Control cat | 4 | 20 | 10 | 0 | 30 | 70 |

The next highest concentration of lead was found in the brain, then the liver, and finally the kidneys. All the tissues examines in the control cat contained considerably less lead. Thus the study of cats showed that lead, in the concentrations found in the air, is capable of being retained and accumulated in the animal organism.

The studies made by M. I. Gusev (1960) on rats under chronic exposure to lead have confirmed that this element accumulates in bones.

From 1952 onwards the results of research on the establishment of maximum permissible concentrations of atmospheric pollutants were published in a special series of papers entitled *Maximum permissible concentrations of air pollutants* under the editorship of Professor V. A. Rjazanov. In view of the fact that data on the biological and physiological effects caused by atmospheric pollution began to predominate in these papers, the title of the series was changed in 1966 to *The biological effect and hygienic significance of atmospheric pollutants.* The 11 collections of papers published so far discuss the scientific basis for setting maximum permissible concentrations for 122 substances that pollute the atmosphere. Even so, a large number of substances that have been introduced in industry, particularly synthetic substances, have not yet been studied from the point of view of sanitary toxicology. At the same time hygienists are constantly working to verify and provide a more precise basis for some of the maximum permissible concentrations already established.

The combined effect of some of the substances most widely encountered in the form of mixtures (sulfuric acid mist and sulfur dioxide, chlorine and nitrogen chloride, nitrogen sulfide and carbon bisulfide, benzene and isopropylbenzene, etc.) is now being studied on an extensive scale.

Initially great importance was attached to determining the sensitivity of methods of measuring atmospheric pollution, and modified methods specially designed for research on air pollution were devised. This work has been summed up by Alekseeva (1959), who describes 35 methods of analysing atmospheric pollutants. A great deal of work has been done on the design of instruments for automating air sampling and air sample analysis. Ljubimov (1961), in collaboration with N. E. Poležaev, designed a gas analyser for sulfur dioxide that makes it possible, over a period of 24 hours, to record concentrations at any one time and the mean concentrations over the whole day. Other authors have also carried out a considerable amount of work on the automation of sampling and sample analysis.

Much attention has been paid to the problem of carcinogenic pollutants in the atmosphere, and it has been demonstrated that it is possible for snow to become contaminated with carcinogenic substances (Šabad & Dikun, 1959). In this connexion Kimina & Poljakov (1961) made the important discovery of the intensive pollution of the environment with 3,4-benzpyrene through the discharge of waste from aluminium factories. Carcinogenic substances in industrial emissions have been studied for the past few decades in a number of the largest institutes of hygiene in the USSR.

In the Ukraine, for the first time in the Soviet Union, a study has begun of the part played by industrial emissions in respiratory allergies. The research is based on experimental reproduction of various models of allergies caused by ingredients in atmospheric pollution. The allergenic activity of a number of chemical substances has now been demonstrated, and study of the threshold of allergenic effect of a number of substances is continuing (Kryžanovskaja et al., 1967).

A number of research institutes are studying radioactive contamination of the atmosphere. In addition to mastering methods of studying background radiation, they have studied the sources of atmospheric pollution with radioactive substances. Measures to protect the atmosphere against radioactive contamination have been proposed (Novikov, 1966).

In recent years more and more attention has been devoted to motor transport as a source of air pollution. Studies by hygienists and toxicologists (Berdyev et al., 1967; Dacenko, 1959; Garbarenko, 1959; Parcef, 1959; etc.) on the effect of motor-exhaust fumes from vehicles operating on various fuels and at various engine speeds have been in progress for a long time, and results have led to the prohibition of the use of tetraethyl lead additive in a number of towns and localities in the USSR, the use of liquefied gas as a motor fuel, etc. The Institute for Research on Motor Vehicles and Vehicle Engines has conducted work on the neutralization of the harmful substances contained in exhaust fumes.

The Central Research and Experimental Design Laboratory for the Study of Pollution Control and Power Problems in Motor Cars and

Tractors is investigating methods of reducing the toxicity of motor exhaust gases.

The ubiquity of motor transport, the large and continually increasing numbers of motor vehicles, their discharge of harmful substances into the air people breathe, and the capacity of exhaust gas components for photochemical transformation all make air pollution by motor vehicle wastes a serious threat to human health.

Furthermore, motor exhaust gases include components such as aerosols of lead compounds, carbon monoxide, and carcinogenic substances, and their control has consequently become of major importance.

It was no accident that, as early as 18 October 1963, the Council of Ministers of the USSR adopted a decree on "Measures to Control Pollution of the Air by Industrial Wastes and Motor Vehicle Exhaust Gases", which expressed, among other things, the need to develop and manufacture appliances for the rapid measurement of harmful substances in motor exhaust gases, for regulating carburettors and fuel systems, and for making the exhaust gases of petrol and diesel engines safe.

Much work in this sphere has been carried out by the Central Research and Experimental Design Laboratory for the Study of Pollution Control and Power Problems in Motor Cars and Tractors (Varšavskij, 1966, 1969).

The principal means of reducing the toxicity of motor exhaust gases is the selection of rational settings for the fuel feed and ignition systems. In petrol-driven cars, the most promising line of research is concerned with lean mixtures, which not only reduce toxicity but are more economical. However, there are a number of difficulties associated with this approach.

An effective way of making vehicle exhaust gases safe is to pass them through a special "neutralizing" apparatus (muffler) fitted in place of the silencer. Platinum and palladium have now been found to be effective neutralizing substances. Test-bench and road trials in the USSR have shown that neutralizers remove 70-80% of carbon monoxide, aldehydes, and hydrocarbons from the exhaust gases.

Suitable regulation of the fuel system can also considerably reduce the content of nitrogen oxides in diesel exhausts. Special fuel additives are being successfully used to control the discharge of soot particles, additives containing alkaline-earth metals (barium in particular) being the best. Test-bench and road trials have shown that the addition of barium to fuels has no effect on the amount of nitrogen oxides, hydrocarbons, and aldehydes in exhaust gases but does cut down the soot content by 70-80%.

In diesel engines, as in petrol engines, the use of mufflers is becoming increasingly common. The fitting of a muffler eliminates the aldehydes in the exhaust gases and reduces the carbon monoxide by 80-90%. Thus, in order to cut down the toxicity of diesel exhausts, it is advisable to combine the two methods by changing over to fuel with barium-based additives and fitting the vehicle with a muffler. Various laboratories in the USSR have tested mufflers of the thermocatalytic, liquid, and combined types. Work on the problem has led to the production of petrol and diesel engines with low levels of toxicity.

In addition, measures have been adopted to rationalize and regulate road traffic. Through traffic is diverted onto by-passes, thus cutting down the probability of hold-ups at cross-roads or traffic lights. The city soviets of Moscow, Riga, Leningrad, and other cities have issued special road traffic regulations and have, among other things, prohibited the use of petrol with tetraethyl lead additives. A successful start has been made on the introduction of gas-powered motor transport in Soviet cities. All these measures are helping to reduce air pollution from vehicle exhaust gases.

As early as 1941, V. A. Rjazanov, in his doctoral thesis *Aspects of town planning from the point of view of the dust problem*, discussed the methods available at the time for studying air pollution and for calculating the smoke content of the air, established permissible concentrations for smoke in urban air, and determined the sanitary requirements to be met by town planning in the light of the meteorological factors influencing the smoke content of the air. He proposed a number of empirical formulae giving the relationships between the smoke content and various meteorological factors.

Later on, Rjazanov (1954) gave a detailed description of the laws governing the dispersion of pollutants in the atmosphere in relation to the quantity emitted, the direction and speed of the wind, the temperature gradient, the humidity of the air, the height and radius of emission, and other factors.

K. G. Berjušov (1962) developed and established the basic hygienic principles of town planning, which would keep the air free of pollution.

The main hygienic principle in Soviet town planning is the clear-cut division of a town into basic functional districts as described below.

(1) Non-industrial built-up areas comprising

(*a*) apartment blocks and residential areas,

(*b*) areas occupied by public buildings and by public service and administrative establishments,

(*c*) green zones for public use in built-up areas, e.g., parks gardens, and squares, and

(*d*) the urban road system.

(2) Industrial areas, reserved for industrial enterprises and power stations, together with their health protection zones.

(3) Municipal and storage areas, reserved for depots and municipal works and installations (parking lots for trams and buses, garages, laundries, etc.).

(4) Areas reserved for intercity transport (railway stations, sea and river-port facilities and landing stages, airports, etc.).

The distribution of the different components of the non-industrial built-up area varies with the size of town, the climatic conditions, and other factors, but a rough indication is given in Table 8.

TABLE 8. DISTRIBUTION OF THE NON-INDUSTRIAL BUILT-UP AREA

| | |
|---|---|
| Residential areas, apartment blocks | 40-55% |
| Areas occupied by public establishments | 15-20% |
| Green zones for public use | 10-25% |
| Urban road system | 20-22% |

From the sanitary and town planning points of view, the main requirement for the siting of industry is a clear demarcation of the town into residential and industrial areas and the establishment of health protection zones between them (see Annex 2).

Industrial establishments must be sited downwind and downstream of the nearest residential area. In the assessment of wind direction account is taken of both the yearly and monthly wind pattern. The prevailing wind is taken as that observed during the hot season, using the mean monthly figures for a large number of years, since at that time of year people spend much more of their time in the open air and keep their windows open. The wind direction in the cold season is also important since it may lead to an increase in air pollution. Owing to the marked decline in atmospheric visibility that occurs when soot is present at a concentration of 0.05 mg/m$^3$, V. A. Rjazanov (1941) proposed that value should be regarded as the maximum permissible mean 24-hour concentration and that the concentration of soot at any one time should not be allowed to exceed 0.15 mg/m$^3$. On this basis also, M. S. Gold'berg (1952) proposed a maximum permissible mean 24-hour concentration of 0.5 mg/m$^3$ for non-toxic dusts in the air of residential areas. Urban dust contains 70–75% of insoluble mineral substances and up to 20% of silicon dioxide. X-ray examination of schoolchildren in Moscow and of children living in an area where the air was heavily polluted with suspended ash discharged from a large thermal power station confirmed that the proposed maximum permissible concentrations for non-toxic dusts were safe and had been correctly established.

B. V. Rihter (1955), in studies of the relationship between atmospheric visibility and the dust content of the air, showed by an integrated flow method that 0.15 $mg/m^3$ of dust reduced atmospheric visibility by no more than 12%, which is quite acceptable as a mean 24-hour concentration.

The principal planning measure for air pollution control, in addition to technical systems, is the establishment of health protection zones around industrial enterprises to separate them from residential areas. These zones allow airborne industrial wastes passing above them to disperse gradually in the air and be retained there. The most effective way to cut down air pollution is to plant the health protection zone with vegetation that is particularly resistant to gases and smoke. The meteorological service is of invaluable help in the planning of such zones.

The Central Hydrometeorological Board runs a number of research institutes, whose contribution in this field has been the study of the diffusion and dispersion processes governing industrial emissions and the development of formulae for the calculation of ground level concentrations. A formula is now available for the rate of dispersion in the air of harmful substances (dust and sulfur dioxide) contained in emissions from industrial enterprises, power stations, and boiler installations. The risk of pollution to the ground layer of air is defined in terms of the maximum concentration of harmful substances at ground level that can build up at some distance from the point of emission under certain meteorological conditions (i.e., when wind speed reaches dangerous levels and strong vertical turbulent exchange occurs).

The maximum ground level concentration $C_{max}$ of harmful substances (in $mg/m^3$) emitted by a single source may be calculated from the formula:

$$C_{max} = AMF \left(\frac{m}{h^2}\right) \left(\frac{1}{v\Delta T}\right)^{1/3}$$

where

$h$ is the height of the chimney above the ground (metres)
$m$ is the mass of the harmful substance discharged per unit time (g/sec);
$v$ is the volume of the air-gas mixture discharged per unit time ($m^3$/sec);
$\Delta T$ is the temperature difference between the gas discharged and the surrounding air;
$A$ is a coefficient depending on the air temperature gradient and defining the conditions of vertical and horizontal dispersion of harmful substances in the air; it is, for example, 200 in Kazakhstan,

160 in the Ukraine, and 120 in the central area of the European part of the USSR;

$F$ is a coefficient allowing for the rate at which harmful substances settle out of the air; and

$M$ is a coefficient allowing for the conditions of discharge from the chimney.

If the emission comes equally from $n$ sources situated close together and with the same height and vent diameters, then the overall maximum concentration is given by the formula:

$$C_{\max} = \text{AMF} \left(\frac{m}{h^2}\right) \left(\frac{n}{v\Delta T}\right)^{1/3}$$

The maximum concentration of any harmful substance must not exceed the maximum permissible one-time concentration for the substance (i.e., $C_{\max} \leqslant$ MPC). Transforming the formula and taking $C_{\max}$ as equal to the maximum permissible concentration (MPC) one can obtain the minimum permissible height $h_{\min}$ for the chimney:

$$h_{\min} = \sqrt{\frac{AMF \, . \, m}{(\text{MPC}) \, (v\Delta T)^{1/3}}}$$

The USSR does not have emission standards. Instead, the maximum permissible emission (MPE), measured in grams per second, is calculated for which the maximum permissible concentration of pollutants in the ground layer of air is not exceeded:

$$(\text{MPE}) = \frac{(\text{MPC}) \, h^2}{AFM} (v\Delta T)^{1/3}$$

Calculation of the maximum permissible emission is a method that takes account of local conditions and thus has an advantage over the use of emission standards.

It should be noted that joint research carried out by the sanitary and meteorological services has shown that there is a good correlation between calculated and actual concentrations of atmospheric pollutants. Extensive use is made of the formulae given above in the design of new industrial plants and power stations.

During the past few years, the Hydrometeorological Service of the USSR has carried out an extensive range of investigations along various lines into the way the atmosphere becomes polluted with industrial waste products. They include theoretical and experimental research designed to develop methods of calculating the dissemination of harmful substances in the atmosphere and to form a basis for practical recommendations on air-pollution control. Regular checks are being made on the degree of pollution in the air of large industrial centres. Over 150 000 air samples have been taken in more than 110 towns of the Soviet Union. Air pollution with dust, sulfur dioxide, carbon monoxide, soot, and other harmful substances has been investigated. The results of

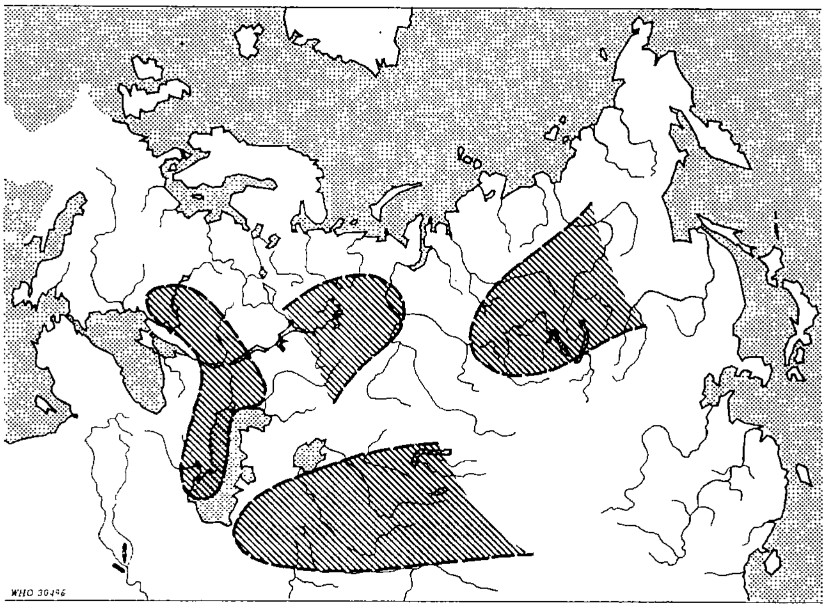

Fig. 1. Areas of the USSR in which towns with the highest degree of air pollution are concentrated

measurements of concentrations of harmful substances in the air at fixed points and along traverses have been analysed. The fixed points are used for determining pollution in particular areas of a town, whereas traverse observations carried out at various distances from individual industrial undertakings show the pollution of the air from specific sources. In considering air pollution in Soviet towns, it has been found that those where pollutant concentrations are most considerable lie in four geographical areas: the south of the European part of the USSR, the Urals, Central Asia, and Siberia (see Fig. 1).

There are grounds for believing that in these areas the intensity of air pollution is determined by climatic conditions as well as by the degree of industrialization. In the summer there is increased turbulent interchange, which causes a considerable movement towards the earth's surface of pollutants discharged by large industrial enterprises. In winter in the same areas cyclone activity in the atmosphere is reduced, thus reducing the cleansing of the urban air by precipitation or strong winds. Analysis of the yearly course of air pollution has often cast doubt on the widespread opinion that pollutant concentrations are higher in winter than at other seasons because of the increased amount of fuel burned. This applies particularly to dust, concentrations of which are as a rule higher in summer than in winter. Measurements of sulfur dioxide concentrations also fail to show any clearcut winter peak. Clearly, an important role is played by seasonal changes in atmospheric processes as well as by variations in the amount of pollutants discharged in the course of the year. To shed more light on this matter, features of the annual course of air pollution with various substances throughout the USSR were analysed. It was found that in several geographical areas air pollution follows a fairly similar annual course, corresponding in the main to seasonal features in the discharge of pollutants into the atmosphere. Over a large area of the European part of the USSR there are two air-pollution peaks during the year, one in spring and one in autumn, corresponding to the two annual peaks in anticyclonic circulation in these areas. The winter peak in Eastern Siberia may be due to the Siberian anticyclone. The summer peak in air pollution in Western Siberia and Kazakhstan is apparently due to an increase in circular exchange combined with low precipitation. Thus, an analysis of data on air pollution in towns and industrial centres in the Soviet Union has revealed evidence that climatic and weather conditions have a substantial effect on the concentration of harmful pollutants in the air (Son'kin, 1969).

Study of the meteorological aspects of air pollution is being carried out in conjunction with institutes and sanitation and epidemiological centres of the Ministry of Health of the USSR and a number of technical and construction concerns. In December 1966 an All-Union Seminar on the Meteorological Aspects of Industrial Air Pollution was arranged by the Central Hydrometeorological Board of the Council of Ministers of the USSR. The purpose of the seminar, at which over 100 research and design bodies were represented, was to review the main practical results obtained during the previous few years that were of common interest to specialists in meteorology, hygiene, industry, and construction.

The A. I. Voejkov Geophysical Observatory, with the help of the F. F. Erisman Institute for Research on Hygiene in Moscow and a number of other organizations, developed a provisional method for calculating atmospheric dissemination of ash and sulfur gases from the smoke stacks of power stations. In 1963 the method was approved by the State Committee for Research Co-ordination of the USSR and since that time it has been widely used by design institutes as a basis for standardizing design calculations for fuel-burning power stations, heat-and-power stations, and boiler installations. It was based on an extensive range of specially conducted theoretical and experimental studies that took into account scientific and industrial experience in the USSR and abroad. Trials have confirmed the correctness of the method. Divergences between measured and calculated concentrations are not systematic and amount to roughly 20–30% (Onikul, 1969). Theoretical and experimental work to test the method still further has continued.

In the next few years studies will also be continued on the following subjects: the effect of air pollution on the living conditions and health of the population, using modern biochemical, immunological, physiological, radiographic, statistical, and other methods of research; the allergenic, mutagenic, embryotropic, and carcinogenic effects of atmospheric pollution; the development of new methods of evaluating the effect of various environmental factors in combination—chemical and physiological, chemical and biological, chemical and radiological, etc.; an experimental basis for the establishment of maximum permissible concentrations of toxic substances in the atmosphere, particularly combinations of substances from different branches of industry, taking into account their various paths of entry into the human body; the laws governing the biological effect of atmospheric pollutants on the basis of homologous series of chemical substances; the link between the chemical structure of substances and their toxicity; the problem of photooxidants in the atmosphere of large cities; the effectiveness of new methods of purifying industrial wastes; the effectiveness of health-protection zones in various branches of industry; the compilation of a map of the country showing morbidity caused by atmospheric pollution; the quicker design of automatic apparatuses for round-the-clock sampling of the main atmospheric pollutants, and the provision of such equipment to research institutes and sanitation and epidemiological centres; and the extension or development of methods of determining atmospheric pollutants and their combinations.

It is also proposed in the coming years to design devices for automatic air sampling, to set up a network of permanent points for regular sampling, and to establish an all-union centre for the collection and processing of data on air pollution and morbidity received from all areas of the country.

In view of the massive rise in agricultural production, the development of large livestock farms, and the creation of large undertakings for the processing of agricultural produce and the manufacture of food products, it is proposed to make wide use of pesticides and mineral fertilizers. Factories are being set up to manufacture building materials from local materials, and many other enterprises are being established in rural localities. All this is of undoubted importance from the point of view of air pollution in the countryside. A further factor that must be mentioned, however, is the large number of tractors used in rural areas, often using lowgrade fuel and contaminating the air with exhaust fumes. Agricultural production has developed to a point where it is creating sources of air pollution in the countryside and it has become necessary for planners and hygienic research workers to treat this problem on an equal footing with other important problems of hygiene affecting rural areas today.

In his study of chemical pollutants in the air and their effect on embryogenesis under experimental and field conditions, V. A. Gofmekler (1970) showed that the intensive use of chemicals in agriculture for plant protection has increased the risk of harmful effects to people living in the immediate vicinity of treated fields. He established a relationship between the degree of atmospheric pollution by organophosphorus pesticides and the number of abnormal pregnancies.

The position in regard to atmospheric pollution in urban areas in the USSR is widely discussed in the pages of such journals as *Gigiena i sanitarija* and *Gigiena truda i professional'nye zabolevanija.* Early monographs on the subject were by Gol'dberg (1948) and Rjazanov (1954). Tomson (1959) dealt with problems of environmental contamination with industrial wastes and the trace elements contained in such wastes. Sabad & Dikun (1959) discussed the pollution of the atmosphere with carcinogenic substances, and Alekseeva (1959) described methods of determining concentrations of pollutants in the atmosphere. Kaljužnyj (1961) dealt with problems of hygiene and sanitary engineering connected with air-pollution control. In addition to literature on the hygienic aspects, technical handbooks have been published on the purification of industrial wastes discharged into the atmosphere (e.g., Zalogin & Šuher, 1954; Užov, 1962).

Aspects of air-pollution control are constantly being discussed at congresses of hygienists in Union republics, at various types of technical conference, and at special meetings. Prospects for the development of research on air-pollution control are discussed at meetings of the Academy of Medical Sciences of the USSR, the All-Union Medical Association of Hygienists and Sanitarians, and the similar associations in the Union republics. In 1969, 13 scientific research institutes and 19 departments of hygiene in medical institutes and institutes for advanced medical studies were participating in work on the problem of air pollution: in all, 120 specific subjects were being investigated. Much is done in Moscow, at the Institute of General and Community Sanitation of the Academy of Medical Sciences of the USSR, the F. F. Erisman Institute for Research on Hygiene, and the Department of Community Sanitation of the Central Institute for Advanced Medical Studies, as well as in Kiev at the Ukrainian Institute of Community Sanitation. The help of sanitary and epidemiological centres is widely enlisted, for the improvement in their technical equipment and in the standard of qualifications of sanitarians is enabling these centres to work on a number of important theoretical and practical studies connected with air-pollution control.

The immense amount of work carried out in the USSR on these problems, the participation in this work of a great number or institutes and scientists, and the heavy expenditure involved are possible only because of the constant concern of the Government of the USSR. An important indication of the ever growing concern with environmental health was the law on the protection of nature in the RSFSR, adopted on 27 October 1960 at the Third Session of the Supreme Soviet of the RSFSR. Article 12 of the law deals with the protection of nature, including the air, against pollution. Under this law it is compulsory, when undertakings and installations are being designed, for ministries and branches of the administration to devise and introduce technological processes ensuring that raw materials and fuel are processed to the maximum possible extent and do not produce harmful waste to be discharged into the atmosphere, water, or soil. If it is impossible to eliminate the discharge of harmful substances into the atmosphere by technological means, the law makes it compulsory to install effective purification and recuperation plant to ensure that the content of these substances in the environment does not exceed the maximum permissible ambient air levels. Similar laws have been adopted in other republics.

The ever increasing rate of industrial development of the Soviet Union, and particularly of its chemical industry, could lead to increased environmental pollution. With a view to strengthening environmental pollution control, standards of hygiene have been accorded regulatory status by the Government in the form of the decree on State sanitary surveillance adopted by the Council of Ministers of the USSR on 29 October 1963. This decree has made it possible to carry out significant combined measures to strengthen further the whole system of sanitation and epidemiological services in republics, *oblasts* and *krajs*, large industrial centres, and the countryside.

Extensive measures are being carried out to control atmospheric pollution and to improve conditions of sanitation and hygiene in the Soviet Union. In more than 100 large towns and industrial centres, a thorough study is being conducted on the effect of air pollution and harmful industrial wastes on the health and everyday living conditions of the population. A significant role in the development of air pollution control in the Soviet Union is being played by a resolution of the Central Committee of the Communist Party of the Soviet Union and the Council of Ministers of the USSR, dated 5 June 1968, embodying measures for the further improvement of public health and the development of medical research in the Soviet Union. This resolution makes it obligatory for the councils of ministers of the Union republics and for ministries and branches of the administration of the USSR to devise and carry out more effective measures for air-pollution control in industrial undertakings.

On 19 December 1969, the Seventh Session of the Supreme Soviet of the USSR adopted a law embodying the fundamental principles of the health legislation of the USSR and the Union republics; this law came into force on 1 July 1970.[1] Division III, section 18, contains the following provisions:

> The wellbeing of the population of the USSR, from the sanitary and epidemiological standpoints, shall be assured by a combination of sanitary and hygienic, and sanitary and epidemic control, measures and by the system of State sanitary inspection. The carrying out of sanitary and hygienic, and sanitary and epidemic control, measures directed towards the elimination and prevention of environmental pollution, the improvement, from the health standpoint, of the working, living and leisure conditions of the population, and the prevention of diseases, shall be obligatory for all State agencies, undertakings, institutions and organizations, collective farms, trade unions and other public organizations.

Section 20 of the same law deals with sanitary prerequisites in the planning and construction of population centres in the following terms:

> Provision must be made for optimal conditions for the life and health of the population in the planning and construction of population centres.
>
> Provision must be made for the following in the planning and construction of towns and urban-type settlements: a water supply, a drainage system, the construction of road surfaces, green zones, street lighting, a sanitary cleansing service, and other amenities. Housing estates, industrial undertakings and other establishments must be sited in such a way as to exclude any adverse effect of harmful factors on the health and sanitary and living conditions of the population.

Section 21 deals with the application of measures for the purification and disposal of industrial, communal and domestic effluents, wastes and refuse. It states:

> The directors of undertakings and institutions and of planning, building and other organizations, and the management boards of collective farms, shall be obliged, when planning, constructing, reconstructing and operating undertakings

[1] An English translation of this law has been published in *Int. Dig. Hlth Leg.*, 1970, **21**, 407-427.

and public services and utilities, to make provision for and apply measures to prevent the pollution of the atmosphere, bodies of water, groundwater and soil, and shall be held responsible for any failure to fulfil these obligations, as prescribed by national and Union republic legislation.

The agencies of the sanitary and epidemiological service shall be empowered to prohibit or temporarily suspend the operation of establishments in service which, by reason of their effluents, wastes or refuse, could have a prejudicial effect on human health.

Thus, the new legislation in the USSR and the Union republics regulates:

public activities in the field of the health protection of the population with a view to ensuring: harmonious physical and spiritual development, health, a high level of working capacity, and a long active life, in citizens; the prevention and reduction of morbidity, a further diminution in the incidence of disabilities, and a reduction in mortality; and the elimination of factors and conditions having an adverse influence on the health of citizens.

These fundamental principles of health legislation declare that the protection of the health of the population shall be an obligation of all State agencies, undertakings, institutions and organizations. At the same time, industrial enterprises, establishments and organizations, trade unions, the Red Cross and Red Crescent Societies, and other public organizations must constantly participate in measures to protect the people's health. It is only by co-ordinating the joint efforts of scientists, public figures, establishments, ministries, and branches of the administration that the environment and the purity of the air we breathe can be protected.

*Chapter 2*

# PRINCIPLES UNDERLYING THE ESTABLISHMENT OF AIR QUALITY STANDARDS IN THE USSR

Air quality is one of the most urgent issues in modern urban life, but its improvement is hampered by the lack of accurate data on which steps to prevent atmospheric pollution can be based, by the lack of adequate technical research on means of preventing or eliminating air pollutants, and by the economic unfeasibility of using many of the means that are available.

Even in countries that have legislation on air-pollution control, there were no air purity standards until recently, and consequently no one knew what level of purity should be aimed at. The establishment of air-quality standards is of cardinal importance, and in the past few years a great deal of attention has been paid to this problem in various countries. The maximum permissible concentrations of air pollutants adopted in the USSR in 1951 were the first standards established anywhere in the world. They were based on the work of a committee under the chairmanship of Professor V.A. Rjazanov.

Regulations governing air purity on the basis of various indices were adopted later in other socialist countries (Bulgaria, Czechoslovakia, German Democratic Republic, Poland, Romania), in the Federal Republic of Germany, in California and other states of the USA, in France, Italy, Japan, etc. A WHO Inter-Regional Symposium on Criteria for Air Quality and Methods of Measurement was held in 1963, and its decisions were discussed by the WHO Expert Committee on Atmospheric Pollutants (1964). In its report, the Committee endorsed the Symposium's recommendations.

The Expert Committee defined air quality standards as the requirements concerning the composition of the air that are laid down by official bodies in the countries concerned. In addition to standards, which have legislative force, there are also "guides", which represent the same requirements before they are approved by the appropriate official bodies. In the Soviet Union and other socialist countries air quality standards are known as "maximum permissible concentrations". However, the WHO Expert Committee did not adopt this term in the belief that it might cause confusion, since it is used in some countries to denote maximum permissible concentrations of substances in the air in industrial undertakings. In the USSR and other socialist countries the terms are synonymous.

The Expert Committee also laid down certain definitions:

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.

In the Soviet standards of air quality, for example, odour or effect on the sensitivity to light of the visual analyser are criteria of this kind. The concept of "guides" was defined as follows :

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

The Committee presented the guides to air quality as four categories or levels of concentration:

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

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

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

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

Thus, the proposed levels are intended to be used in evaluating the degree of harmfulness of atmospheric pollution, starting with harmless and ending with lethal concentrations. Obviously only Level I corresponds to the concept of maximum permissible concentrations and represents that condition of the atmosphere that we must strive to achieve. This is in fact the hygienic standard that in the USSR serves to define the maximum permissible concentration, namely: the concentration that causes no direct or indirect, harmful or unpleasant effects to man and impairs neither his ability to work nor his mental or physical well-being. Such a concentration may, of course, be above or below that attainable in practice and ordinarily found in the air. For this reason, as a temporary expedient, sanitary or technological standards may be used as a guideline.

Air quality standards can be based on hygienic, sanitary, or technological considerations.

Hygienic standards are requirements that meet the interests of man as a biological species. They are aimed at providing environmental conditions completely favourable for man from the physiological point of view. Not only do they have no adverse effect on him, they also ensure his biological comfort or the hygienic optimum.

Sanitary standards are hygienic standards corrected for factors in the current situation: technical and economic feasibility. These standards represent a concession to practical possibilities and are therefore of a temporary nature. They may differ in different countries and at different times in the development of an economy.

The third group, technological standards, are aimed at preventing, in so far as is justified by economic considerations, the discharge of harmful substances into the atmosphere.

Hygienic standards are of the greatest importance to public health, and they include the maximum permissible concentrations adopted in the USSR and other socialist countries.

## CRITERIA AND METHODS FOR ESTABLISHING MAXIMUM PERMISSIBLE CONCENTRATIONS OF ATMOSPHERIC POLLUTANTS

In the USSR it was decided to recognize as permissible only those concentrations of atmospheric pollutants that have neither a direct nor on indirect harmful or unpleasant effect on man, do not impair his working capacity, and do not have a detrimental influence on his feeling of physical wellbeing or his mood. Concentrations that have a detrimental effect on vegetation, local climate, the transparency of the atmosphere, living conditions, etc., are also considered impermissible.

In establishing maximum permissible concentrations, use is made of all the data from toxicologists and experts in industrial health on the effect of various toxic substances on the human organism. It must be remembered however, that these data can serve only as a tentative guide, since industrial toxicology is concerned with very high concentrations of poisonous substances such as do not occur in the open air. In addition, the conditions facing the population living in large towns and those facing industrial workers differ sharply, and this makes it impossible to extrapolate to the general public the results of observations made on workers. The main difference is that the worker is exposed to poisonous substances for 8 hours a day and the general public for the whole 24 hours. The workers represent the physically strongest portion of the population, whereas a considerable proportion of towns folk have a higher-than-average susceptibility to poisoning: old people, small children, and persons with various chronic diseases. In addition, the maximum permissible concentrations laid down for workers are usually based on very rough methods of research and are therefore considerably higher than they ought to be.

In establishing maximum permissible concentrations for air pollutants in the USSR, wide use is made of special toxicological experiments on animals and observations on human beings. The animals are kept in exposure chambers with a continuous intake of air containing an admixture at known concentrations of the substances being studied. In the first stage of the investigations, the animals are exposed for 6 hours a day over a period of 6 months. In the second stage they are exposed continuously during the whole 24 hours for 3 months, thus providing a closer approximation to conditions of human exposure in the urban environment. The work is usually conducted at low concentrations, and for that reason no appreciable changes in behaviour are discovered. The weight of the experimental animals does not differ significantly from that of the controls. Explicit functional changes do occur, however, as can be determined by objective methods.

In establishing a basis for maximum permissible concentrations of air pollutants, great importance is attached to long-term changes in the higher nervous activity of animals as a result of the inhalation of toxic substances. It is well known that changes in the functions of the cerebral cortex occur very early and at low concentrations, since the cortex is most sensitive to exposure to environmental factors (Izmerov, 1971a). A dynamic stereotype is first established in the animals, which are then exposed to the toxic substance. Once every day or two days during exposure, the animals are observed to see if any changes have occurred in the stereotype. The changes that arise in the higher nervous activity of animals are quite uniform in type and do not depend essentially on the substances used, for the differences lie only in the size of the threshold concentration. One of the early signs of the effect of various chemicals on the higher nervous activity is the development of phasic states. Then the powers of discrimination are lost, and eventually all the reflexes in the stereotype are gradually extinguished. When more serious damage occurs, the natural conditioned reflex to the sight and smell of food also disappears. The conditioned reflex method has proved a highly sensitive means of establishing a basis for maximum permissible concentrations of atmospheric pollutants. Concentrations of mercury, lead, benzine, etc. considerably below the maximum permitted concentration for workshops have been found to cause marked changes in the higher nervous activity of rats (Rjazanov, 1961c). To assess the functional condition of the cerebral cortex, Soviet hygienists also study the ratio between the chronaxies of antagonistic muscles. While the absolute value for chronaxy depends on both central and peripheral phenomena and changes in it are not a sensitive indicator of the condition of the cerebral cortex, the chronaxy ratio is determined by central effects and is an extremely sensitive indicator of the effect of toxic substances on the condition of the brain. In the case of furfural, for example, levels of only one-thirtieth of the maximum permissible concentration for workshops proved to be active (Ubajdulaev, 1963).

Inasmuch as processes of excitation and inhibition in the organism are closely connected with the functioning of the mediators, it is important to find out whether or not a particular concentration of a given substance causes a change in cholinesterase activity. In a number of papers it has been shown that changes in cholinesterase activity are caused by concentrations lower than the maximum permissible concentrations for industry (Odašišvili, 1963). This method has been recommended as sufficiently sensitive to determine the effect of small concentrations of atmospheric pollutants on the animal organism in long-term experiments.

Another very sensitive test used in the USSR to study the effect of atmospheric pollutants is determination of urinary excretion of coproporphyrin. It has been established that carbon monoxide, dinile, styrene and dimethyl formamide reduce the amount of coproporphyrin excreted in the urine, while lead and toluylene diisocyanate increase it. The concentrations of various toxic substances that act on coproporphyrin metabolism are below the maximum permissible concentrations for air in industrial undertakings.

The inhalation of small concentrations of some atmospheric pollutants leads to changes in the degree of dispersion of the serum proteins. The ratio changes between the coarsely dispersed proteins—globulins—and the finely dispersed ones—albumins. The content of albumins decreases while that of the globulins increases. Like many other non-specific changes within the body, a disturbance of the normal ratio between the blood serum protein fractions is an indication of changes detrimental to the organism.

A number of other functional changes are found following chronic exposure to atmospheric pollutants; although they do not explicitly indicate pathological changes, they do show that protective and adaptive or purely adaptive changes have occurred, indicating that the body is out of balance with its environment. All these changes are taken into account by Soviet hygienists when maximum permissible concentrations of air pollutants are being established.

The results of long-term animal exposure experiments serve as a basis for determining the average daily concentrations, which are designed to prevent the chronic effects of inhalation of toxic substances by the population. In the USSR a distinction is made between two types of indicator of the degree of atmospheric pollution: average daily concentrations and maximum permissible single concentrations.

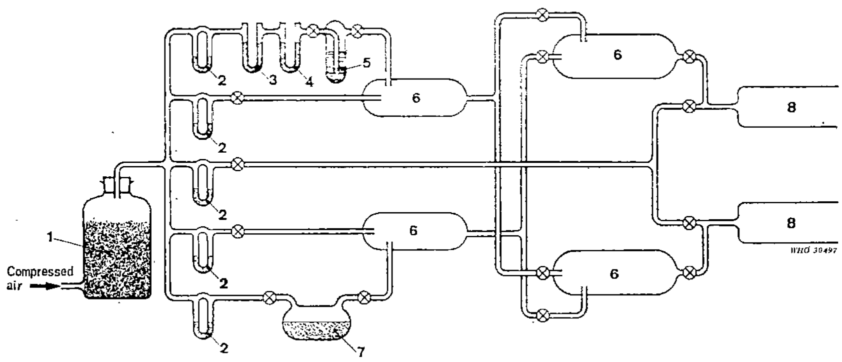


Fig. 2. Apparatus for determining the olfactory threshold

1. Activated carbon. 2. Flowmeters. 3. U-tube with calcium chloride. 4. U-tube with activated carbon saturated with chlorine. 5. Absorber with distilled water. 6. Mixing vessels. 7. Test substance. 8. Odour sampling tubes.

The establishment of maximum permissible single concentrations of atmospheric pollutants is designed to prevent a level of pollution that may cause reflex reactions through irritation of the receptors in the respiratory tract, particularly in the olfactory region of the nasal cavity. Soviet hygienists believe that the atmosphere should not have an odour that the public finds undesirable. Practice shows that the population protests vigorously against contamination of the air with extraneous and malodorous substances, including industrial emissions. In view of this, when a basis is being sought for maximum permissible single concentrations of atmospheric pollutants, wide use is made of studies of the olfactory threshold for various pollutant substances, the observations being made on a group of volunteers. Suitable equipment is shown in Fig. 2. The olfactory threshold in the most sensitive volunteer is taken as a basis for determining the maximum permissible concentration, which should be imperceptible for the whole group. It is known that substances capable of irritating the receptors of the nasal cavity and upper respiratory tract also provoke a number of reflexes:

they alter the frequency and amplitude of respiratory movements, cause spasm of the vocal chords and the bronchial muscles, change the tone of the blood vessels, and alter the functional condition of the brain. These reactions are also studied when a basis is being sought for maximum permissible concentrations. Changes in the rhythm and rate of respiration take various forms, such as an increase in the breathing rate accompanied by a reduction or unevenness in amplitude. In most cases changes in respiratory movements have been found only at concentrations that are subjectively perceptible, e.g., through odour or irritation of the nasal or laryngeal mucosae.

Determination of optical chronaxy is a method widely used in Soviet hygienic research. After determining it several times in the subject, the investigators allow him to inhale a certain concentration of the gas concerned and then determine the chronaxy again. As a rule an increase in optical chronaxy occurs after exposure to odorous substances, indicating reduced excitability of the central nervous system. According to Pavlov,[1] excitation in one area of the cerebral cortex may cause inhibition in other areas through operation of the law of negative induction. According to this theory, the excitation in the olfactory area of the cerebral cortex causes inhibition in the visual area. This inhibition is of a reflex nature, as is shown by its rapid disappearance once irritation of the olfactory centres has ceased. It should be noted that when the concentrations of the gases concerned are increased the reaction becomes more intense and sometimes longer-lasting as well. The task of hygienists is to determine the minimum concentration, i.e., the threshold, at which the reaction occurs. Optical chronaxy changes only at concentrations equal to or above the olfactory threshold. Data obtained by pneumography and optical chronaximetry have shown that the threshold of smell is an important hygienic parameter, since it characterizes not only the possibility of subjective perception of the substance when inhaled but also the possibility of reflex reactions due to inhibited excitability in other regions, such as changes in the external respiration or, still more important, changes in the functional condition of the cerebral cortex, including the cortical visual regions. This confirms the need to oppose the discharge into the air of odorous substances in concentrations above the olfactory threshold.

Chronaximetry, however, like pneumography, has proved insufficiently sensitive to detect the presence of subliminal, i.e., unperceived, reflex reactions in the olfactory receptor. Soviet hygienists have therefore begun to use adaptometry—the study of the dark adaptation

[1] See: I. P. Pavlov, *Lekcii o rabote bol'ših polušarij golovnogo mozga* [Lectures on the work of the cerebral hemispheres], a new edition of which was published by Medgiz, Leningrad, in 1952.

of the eye. The adaptometer makes it possible to measure the increase in the light sensitivity of the eye in the dark. The required concentration of the gas is fed into a cylinder from which the subject breathes for 4-5 minutes between the fifteenth and twentieth minutes of adaptation. After this he is again given pure air. At the twentieth minute very significant changes in light sensitivity appear, which differ in nature depending on the concentration of the gas being tested. If the concentrations are relatively high there is a fall in light sensitivity; the higher the concentration the more marked the fall and the longer it persists. At very low concentrations there is an increase in light sensitivity, which is not followed by a reduction to below the normal level. At still lower concentrations no substantial changes occur in the dark adaptation curve. The minimum concentration at which statistically significant changes can be detected in the course of adaptation is taken as the threshold. The changes in light sensitivity found by this method are in good agreement with the views of the Russian physiologists Pavlov and Vvedenskij.[1] Weak stimuli cause excitation and strong stimuli cause inhibition of nervous activity. Once excitation has reached a certain level, it is transformed into its opposite—inhibition. In the course of research on dark adaptation it has been noted that some substances cause changes in light sensitivity at concentrations not perceptible to the sense of smell. For example, the olfactory threshold for sulfur dioxide is 1.6 $mg/m^3$, while the threshold of effect on light sensitivity is 0.6 $mg/m^3$. The figures for furfural are 1.0 and 0.3 $mg/m^3$ respectively. This fact is of great importance from the point of view of hygienic research. It suggests that we must not be content with the absence from the atmosphere of pollutants in concentrations capable of being perceived by the sense of smell. We must insist that concentrations are not only below the olfactory threshold but also below the threshold of subconscious reflex reactions capable of changing the functional condition of the cerebral cortex.

It is interesting that by no means all substances are capable of causing subliminal changes in light sensitivity. For example, formaldehyde, sulfuric acid, chlorine, and hydrogen chloride are capable of changing light sensitivity only in concentrations perceptible to the sense of smell.

It has been suggested that substances with an olfactory effect (i.e., those that primarily irritate the olfactory nerve endings) could cause subsensory reactions, whereas substances with a trigeminal effect (i.e., those that primarily irritate trigeminal nerve endings) are unable to

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[1] These early studies are reported in I. P. Pavlov, *Lekcii o rabote bol'ših polušarij golovnogo mozga* [Lectures on the work of the cerebral hemispheres], published by Medgiz, Leningrad, in 1952, and in N. E. Vvedenskij, *Izbrannye sočinenija* [Selected works], volume 2, published by Medgiz, Leningrad, in 1951.

produce such reactions. This suggestion, however, needs careful experimental checking.

For many years the adaptometer method remained unsurpassed in sensitivity as a method of detecting reflex reactions involving the receptors of the nasal cavity and upper respiratory tract and the functional condition of the cerebral cortex. Buštueva, Poležaev & Semenenko (1960) laid the basis for the use in hygienic research of the various types of electroencephalography. This method has proved even more sensitive than adaptometry. Thus, in experiments using the light sensitivity method, the threshold of activity for furfural was 0.3 $mg/m^3$; with the method of electrocortical conditioned reflexes it was 0.08 $mg/m^3$. The corresponding figures for styrene were 0.02 and 0.005 $mg/m^3$ (Li Shen, 1963).

The advantage of this method over the others, and particularly over adaptometry, lies in its simplicity and high degree of sensitivity. Persons who show a well marked alpha rhythm are selected for observation. The investigations are carried out in an electrically screened chamber under conditions of quiet. Every time the subject is given a light signal, temporary desynchronization of the alpha rhythm occurs. When the light is switched off, the alpha rhythm returns to normal. The subject is given a substance to inhale, in a precisely known concentration that will not in itself cause desynchronization of the alpha rhythm. When the subject has inhaled the gas for 10 seconds, he is given a light signal lasting 5 seconds. After this combination of gas inhalation and light signal has been repeated several times, it is found that desynchronization begins to occur before the light signal is given, i.e., in response to the imperceptible odour. The imperceptible odour thus becomes a conditioned stimulus and causes the establishment of what is known as a "conditioned electrocortical reflex". This reflex makes its appearance after 6–8 combinations of light signal and gas inhalation and persists until roughly the twentieth combination, after which it gradually disappears. Practice shows that not every concentration of an odorous substance will cause the establishment of a conditioned electrocortical reflex. This reaction has its own threshold: after repeated series of tests with various concentrations of gases, the concentration that will not cause the reflex to become established is finally discovered. This figure is taken as one of the criteria for establishing the maximum single permissible concentration.

Although Soviet hygienists attach great importance to experimental methods of establishing maximum permissible concentrations of atmospheric pollutants, this does not mean that they neglect the use of morbidity surveys. Such surveys have been carried out by many scientists —including M. S. Gol'dberg, M. S. Sadilova, M. I. Gusev, D. N. Kaljuznyj, and A. V. Mnacakanjan—and it has been found that people living in urban areas with a highly polluted atmosphere show higher morbidity rates than those living in places where the air is unpolluted. Data of this kind, however, are interpreted with great caution since it is difficult to ascribe an increase in morbidity with any certainty to atmospheric pollution alone. The most reliable information on the connexion between morbidity and air pollution can be obtained by studying the health of the child population, particularly if it is possible to carry out special medical examinations of a sufficiently large number of children of the same age living in areas with different levels of pollution.

A number of studies have recently been carried out to determine the types of combined action exerted by various substances when present in the air together (Gusev et al., 1968). The results are given in Table 9; they show that the combined effects of toxic substances present in the air in threshold or subthreshold concentrations are in most cases a simple sum of their individual effects.

The occurrence of protective reactions indicates that the condition of the environment has deviated from the physiological optimum, i.e., the hygienic norm. If, therefore, protective and adaptive reactions occur in response to the inhalation of atmospheric pollutants, this is considered as proof that the external environment does not meet the requirements of hygienic comfort. Maximum permissible concentrations of air pollutants should not cause such reactions. Although the study of morbidity helps to establish that atmospheric pollution is extremely high, it cannot help in determining maximum permissible concentrations, i.e., the concentrations that do not encroach on hygienic comfort. The task of hygiene in the Soviet Union is not only to prevent disease but also to provide the population with conditions corresponding to the biological optimum (Rjazanov, 1965b).

Very often maximum permissible concentrations, including the inevitable safety factor, have proved to be inactive not only separately but also in combination.

In determining maximum permissible concentrations, it has been proposed that a minimum and standard safety factor of 30% be used in every case. This means that the intervals in a range of concentrations should be 30%. When a presumed threshold value is found, the next concentration investigated should be 30% lower. If that proves inactive, the investigation need not continue. If it does not, the investigations must be continued with a concentration 30% lower than the previous one. Once an inactive concentration is found, the investigation comes to an end.

As already stated, various factors are used as a basis for establishing

TABLE 9. OVERALL INDICES OF THE COMBINED ACTION OF TOXIC SUBSTANCES IN THE AIR

| Substances in combination | Way in which the effects combine | Standard recommended for the given combination [a] | Author |
|---|---|---|---|
| chlorine<br>hydrogen chloride | partial summation | apply MPC for each substance | V. M. Stjažkin |
| sulfur dioxide<br>sulfuric acid | simple summation | apply formula $\leqslant 1$ | K. A. Buštueva |
| hydrogen sulfide<br>carbon disulfide | partial summation | apply MPC for each substance | B. K. Bajkov |
| sulfur dioxide<br>phenol | simple summation | apply formula $\leqslant 1$ | A. P. Mahinhja |
| phenol<br>carbon monoxide | " | " | E. F. Elfimova |
| phenol<br>acetone | " | " | U. G. Pogosjan |
| phenol<br>acetophenone | full summation | apply formula $\leqslant 1.5$ | Ju. E. Korneev |
| acetophenone<br>acetone | " | " | N. Z. Tkač |
| isopropylbenzene<br>isopropylbenzene hydroperoxide | simple summation | apply formula $\leqslant 1$ | G. I. Solomin |
| ethylene<br>propylene | " | " | M. L. Krasovickaja |
| butylene<br>hydrogen sulfide<br>carbon disulfide | " | " | H. H. Mannanova |
| dinyl<br>isopropylbenzene<br>benzene | " | " | E. V. Elfimova |
| nitric acid<br>sulfuric acid<br>hydrochloric acid | " | " | V. P. Melexina |

[a] See explanatory notes to Annex 1.

hygienic standards in the Soviet Union. The primary factors to be taken into account are the direct effect of the pollutant on man, the threshold of acute topical and general toxic effect, the threshold of long-term effect, the threshold of irritant effect on the mucosae, the threshold of olfactory sensation, etc. However, the immense importance of subjective evaluation of atmospheric pollution must not be forgotten.

Complaints from the public regarding smells emanating from a particular industrial plant must be taken into account.

In addition to the direct effect of atmospheric pollutants on man, their indirect effect is also taken into consideration. Concentrations of smoke should not be permitted if they appreciably reduce the transparency of the atmosphere, the amount of daylight in houses, or the intensity of ultraviolet solar radiation, or if they increase the frequency of fogs, since all these climatic changes have a detrimental effect on the health and wellbeing of man. Special allowance is made for the effect of harmful gases on vegetation in towns, which is of great importance for urban hygiene; a concentration that has a detrimental effect on vegetation is not considered permissible. In view of the immense variety of factors that must be taken into account when standards for atmospheric pollution are being established, the correct approach is considered to be to calculate the total harmful effects of a particular admixture in the air and to use the "critical parameter" principle. This means that the standard must be based on the criterion that proves most sensitive. Thus, if a gas is perceptible by odour at concentrations below those with a harmful effect on vegetation, the standard for that gas should be based on the threshold of olfactory sensation. On the other hand, if concentrations that have a toxic effect on man can be distinguished neither by odour nor by their irritant effect on the mucosae, the standard will be based on the threshold of toxic effect (Rjazanov, 1952b).

In the USSR, maximum permissible concentrations are mainly established by experiment, i.e., by the study of the biological effects of exposure to accurately determined concentrations of atmospheric pollutants. Full-scale studies of the population are then made in order to check on the reliability of the standards established.

The body of experimental work on air pollution that has been built up in the USSR has made it possible to formulate laws governing the biological effects of atmospheric pollutants. The most important of these laws are considered in the following paragraphs.

In the concentration ranges concerned, atmospheric pollutants may provisionally be divided into three groups: substances affecting the organs of smell, substances affecting the trigeminal nerve, and substances with a predominantly resorptive effect.

Substances in the first group are distinguished by their odours, but they also produce a reflex response in a person inhaling them briefly at subsensory levels. Typical members of this group are sulfur dioxide, phenol, and the vapours of organic solvents.

Substances acting on the trigeminal nerve have an irritant effect. The thresholds of the irritant and reflex effects are generally the same. Sulfuric acid mist is a member of this group.

Study of the nature of the response to substances affecting the organs of smell or the trigeminal nerve (Začinjaeva et al., 1970) has shown that inhalation of such substances at subsensory levels produces an orienting-investigative response, the specific olfactory response not appearing until concentrations have reached sensory levels.

Substances in the third group, which are odourless and nonirritant (e.g., carbon monoxide), do not generally produce a reflex response when inhaled briefly. However, as recent research has shown (Mamacašvili, 1968), lengthening the period of exposure to carbon monoxide to 30 minutes will produce a reflex response, possibly due to reflex action of the chemoreceptor carotid ganglion, following absorption of carbon monoxide by the blood.

When substances affecting the organs of smell and the trigeminal nerve are present together in air that is being inhaled, they produce a reflex response which is a simple sum of the individual effects of each pollutant (Buštueva, 1961b).

Research into the effects of a combination of substances affecting the organs of smell and substances with a pronounced resorptive effect (e.g., sulfur dioxide and carbon monoxide) has indicated that the effects produced by each component of the mixture are independent of one another. However, further research is needed to clarify this relationship properly.

Study, in experimental animals, of the resorptive effects of a long period of continuous exposure to atmospheric pollutants has shown that small concentrations of such pollutants will produce nonspecific changes in various organs and systems, such as modification of cholinesterase activity in the blood, changes in the 17-ketosteroid and coproporphyrin levels in the urine, and alteration of the relative proportion of protein fractions and sulfhydryl compounds in the blood.

Such nonspecific changes are observed to follow exposure to subtances belonging to various classes of chemicals and they may well represent a defense or adaptive response of the organism to the effects of atmospheric pollutants. This view is supported by the fact that the various disturbed functions return to normal 2–3 weeks after exposure has been discontinued.

Substances affecting the organs of smell or the trigeminal nerve cause changes in animals only when used at concentrations on the olfactory threshold, the irritation threshold or, sometimes, the reflexive-effect threshold, even in the case of long exposures. No data are as yet available to explain this phenomenon, but it is possible that either the methods used to study the resorptive effect are not sensitive enough or the changes taking place in the animal organism are masked by compensatory processes.

Animals being used as models of various disorders (e.g., pulmonary insufficiency, hormonal insufficiency) are more susceptible to prolonged exposure to chemicals than are healthy animals (Čižikov, 1970).

Prolonged exposure to certain chemicals, such as sulfur dioxide, nitrogen dioxide, carbon monoxide, benzene, formaldehyde, and diethylamine, in concentrations liable to occur in the atmosphere, is embryotoxic and gonadotoxic to experimental animals. Such effects are sometimes retained in the first generation offspring of affected females (Gofmekler, 1967).

These basic rules were discovered in experimental work on the biological effects of atmospheric pollutants and are used by Soviet hygienists in establishing national standards.

The questions naturally arise of the biological significance of the reflexive and resorptive changes produced in experimental animals and of the relevance of such changes to the health of people exposed to polluted air. In the case of resorptive changes, in particular, it is generally doubtful, in view of the variations in specificity, whether the findings of such experiments can be extended to man. For this reason it is advisable to check the results under full-scale conditions.

The USSR has developed research into the effects of atmospheric pollutants on man, making extensive use of physiological and biochemical tests. Such studies, being generally carried out on children, reveal changes in the organism that are compensatory rather than pathological in nature. They thus show great promise as a means of detecting the effects produced by low concentrations of atmospheric pollutants.

A comparison of the results of some recent experimental and full-scale studies is given in Table 10. A comparative assessment (Buštueva, 1971), based on the data in this table, has shown that the results of experimental work on the resorptive effect in animals may legitimately be extended to man and are thus perfectly reliable for establishing maximum permissible mean 24-hour concentrations of atmospheric pollutants.

Long-term changes in the adaptive capacity of the body, recorded as changes in biochemical and physiological processes, cannot be ignored. They can affect some health indices, such as the physical development of the child and morbidity from infections of the upper respiratory tract. Before this relationship can be finally clarified, more information will have to be collected through simultaneous studies of health indices in children. Research is also needed to determine which factor is the cause and which the effect—the physical and biological changes or the changes in health indices. The answer to this may be facilitated by analysis of the results of full-scale studies.

# TABLE 10. COMPARATIVE ASSESSMENT OF EXPERIMENTAL AND FULL-SCALE STUDIES ON THE BIOLOGICAL EFFECTS OF ATMOSPHERIC POLLUTANTS [a]

(all concentrations expressed in mg/m³)

| Substance | Approved MPC | Experimental studies: Odour, threshold | Odour, sub-threshold | Reflex effect, threshold | Reflex effect, sub-threshold | Resorptive effect, threshold | Resorptive effect, subthreshold | Full-scale studies [b]: Physiological and biochemical changes, present | Physiological and biochemical changes, absent | Change in morbidity, physical development, or blood, present | Change in morbidity, physical development, or blood, absent | Reference |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monoethylamine | 0.01/0.01 | 0.05 | 0.04 | 0.004 (EEG) | | 0.05 Fall in sulfhydryl compounds and cholinesterase activity in the blood; changes in the coproporphyrin content of the urine. | 0.01 | 0.028/0.011 Changes in the threshold of smell, cholinesterase activity, and coproporphyrin in urine. | 0.0006/— | 0.028/0.011 Increase in child morbidity from acute infections | 0.006/— | Tkacev, 1969 |
| Arsenic trioxide (calculated as As) | —/0.003 | — | — | — | — | 0.005 Fall in sulfhydryl compounds and cholinesterase in the blood; accumulation of arsenic in organs. | 0.0013 | 0.0027/— | 0.005-0.0009/— 0.0041/— Arsenic found in children's hair. | — | — | Rozenštejn, 1970 |
| Lead oxide (calculated as Pb) | —/0.0007 | — | — | — | — | —/0.10 Modification of higher nervous activity; change in the coproporphyrin content of urine; lead in the bones. —/0.0039 Modification of higher nervous activity; lead in the bones. | —/0.0011 | —/0.001 and 0.0025 Increase of coproporphyrin and lead in children's urine. | —/0.00027 | — | — | Gusev, 1961 |
| Chloroprene | 0.1/0.1 | 0.3 | 0.25 | 0.2 | 0.1 | 0.22 Fall in sulfhydryl compounds, cholinesterase, and 17-ketosteroids. | 0.088 | —/0.26 Change in coproporphyrin and 17-ketosteroid content of urine. | —/0.13 | — | — | Mnacakanjan, 1964; Mnacakanjan & Mušegjan, 1964 |
| Sulfur dioxide + nitrogen oxides | Given by the formula for a simple sum [c] | 1.6 / 0.23 (in combination: simple sum) | 1.3 / 0.11 | 0.6 / 0.14 | 0.5 / 0.09 | 0.15 + 0.10 Changes in sulfhydryl compounds, coproporphyrin, central nervous system, and cholinesterase; histological changes. | 0.078 + 0.052 | —/0.32 + —/0.099 Increase in activity of blood catalysts. | —/0.19 + —/0.063 | —/0.32 + —/0.099 Change in physical development and lymph glands. | | Šalambe-ridze, 1969 |

[a] In the table the figure preceding the oblique stroke refers to the one-time concentration and that after the oblique stroke to the mean 24-hour concentration.

[b] Carried out on groups of children selected on the basis of socioeconomic background and housing and living conditions.

[c] See Annex 1 (notes)

The orienting-investigative response, which occurs initially on inhalation of atmospheric pollutants, generally disappears in the course of time (although it reappears if the external conditions are changed). This raises the problem of the relationship between the reflex effect of atmospheric pollutants and the adaptive response to long-term exposure, the solution of which will help in assessing the biological significance of the reflex response.

## CONCENTRATIONS OF ATMOSPHERIC POLLUTANTS AND THEIR INTERPRETATION

On the basis of the above principles, criteria, and methods for establishing scientifically based hygienic standards for atmospheric pollutants, the USSR in 1951 laid down national standards—the first in the world—in the form of maximum permissible concentrations for the 10 most frequently encountered air pollutants. In the 20 years that have elapsed since then, the original standards have been revised and research has made it possible to lay down maximum permissible concentrations for more than a hundred substances and 20 combinations of substances encountered in the urban air (see Annex 1).

In 1949, V. A. Rjazanov laid down the principles governing the establishment of hygienic standards for atmospheric pollutants. These principles led to the following criteria.

(1) The only permissible atmospheric concentration of a given substance is that which causes no direct or indirect, harmful or unpleasant effect in man and which does not impair either his ability to work or his mental or physical wellbeing.

(2) Habituation to harmful substances must be considered as a harmful sign and is proof that the concentration in question is above the permissible level.

(3) Other impermissible concentrations are those at which atmospheric pollutants have a harmful effect on vegetation, local climate, atmospheric visibility, or human living conditions.

It is the usual practice in the Soviet Union to express clean-air standards in terms of weight per unit volume of air, usually in $mg/m^3$. The maximum permissible concentrations relate to the place in which people live. There is hygienic basis for setting standards for the composition of smoke and gases discharged into the atmosphere, since they act on man only when they reach his dwelling area, by which time they have been considerably diluted. For a constant concentration of a harmful substance in the effluent, the concentration in residential areas may differ according to such factors as the volume of gas discharged, the duration of discharge, the height of the stack, and its distance from the point concerned. The important question is whether concentrations of atmospheric pollutants should be expressed as maximum momentary concentrations, maximum mean daily concentrations, maximum mean monthly concentrations, etc. The effect of harmful substances depends, of course, not only on concentration but also on exposure time. A given concentration may be absolutely harmless when exposure is brief but may become dangerous after a number of hours, days, or months. For that reason it is the usual practice in the USSR to set standards for generally toxic substances, particularly those with a cumulative effect, on the basis of mean concentrations—the mean concentration per shift in the case of industry and the mean concentration per 24 hours for the open air. Since the concentration of pollutants in the atmosphere varies widely, stipulation of the mean daily concentration alone does not guarantee that concentrations will not rise above the threshold of acute effect for a short period. For that reason the mean daily concentrations are supplemented by the permissible range of fluctuation, i.e., the maxinum permissible momentary or "peak" concentrations.

Standards for gases that do not have a general toxic effect are based on their irritant effect on the mucous membranes or on their odour. In such cases the maximum momentary concentrations are used, since lengthy exposure is not required for odour or irritation of the mucosae to occur. In the case of gases distinguished by their combined effect, both the momentary and the mean concentrations are used. The Committee for the Establishment of Maximum Permissible Concentrations of Atmospheric Pollutants in the Soviet Union recommended that calculations be made for two levels: the breathing level of pedestrians (conventionally 1 m above the ground) and the level of the windows of the upper storeys of the highest buildings. Calculations should be made for points on the border of the health-protection zones, and also within the built-up area at various distances from the point of emission of the pollutant. In other words, a concentration distribution curve must be calculated to determine the concentrations of the pollutant as it moves further from the point of emission. Wind direction must be taken into account when maximum single concentrations are being calculated. When maximum mean daily concentrations are being calculated, the figure used for the percentage frequency of winds blowing from the point of emission towards the sampling point should be the average for the most unfavourable month. Since it is well known that concentrations of atmospheric pollutants depend very closely on wind speed, it is essential to determine what wind speed to use in the calculations. It is recommended that it should be the speed corresponding to the upper limit in the "calm weather" category, i.e., 0.5 m/sec. Cases may occur when, at a particular point, the usual laws governing the reduction in concentration as wind speed increases prove inapplicable; calculations should therefore be made for higher wind speeds as well. If there are several sources of pollution, a separate calculation must be made for each source and each pollutant. The total concentration should not exceed the maximum permissible level. In determining the maximum single concentration, samples of air are taken at the given point at the times when the air is most polluted, i.e., when the point lies in the path of the airstream from its main source of pollution, when that source is working at full capacity, and when meteorological conditions are unfavourable.

It is particularly desirable to take samples during anticyclones, temperature inversion, or fog. The most unfavourable season of the year must be selected for each pollutant: the worst season for sulfur dioxide, for example, is the winter. Wherever possible the duration of sampling for each particular substance should not exceed 10–20 minutes. To avoid obtaining results that are too low it is essential to keep a strict watch on the wind direction; if it changes so that the sampling point is no longer in the stream of gas emitted by the industrial plant concerned, sampling should be stopped. The total number of samples taken in such conditions should be at least 25. Sampling for mean daily concentrations should make no allowance for changes in wind direction, i.e., sampling should continue even if the sampling point is no longer in the path of the smoke plume. When samples are being taken for mean daily concentrations, however, the periods of maximum pollution of the air must be selected—when the industrial enterprise concerned is working at full capacity during the most unfavourable season of the year; when there is anticyclonic weather, fog, or no wind; and particularly when the wind is blowing from the source of pollution towards the sampling point. By selecting sampling times in this way the maximum mean daily concentration can be determined, but not the mean for a month or a year. The number of mean daily samples taken in this way should be at least 10. The following procedure is used to assess the results: pollution at the observation point is considered to exceed the norm if the concentrations in any two or more samples exceed the maximum permissible concentrations. If only one sample exceeds the maximum permissible concentration, sampling is repeated; if one further sample exceeding the maximum permissible concentration is obtained, it is concluded that the air pollution exceeds the permissible maximum.

The maximum permissible concentrations worked out in the USSR should not be considered as final values. Experience has shown that they may need to be revised in the light of further research. Maximum permissible concentrations are kept under constant review and are improved as new scientific data become available. The methods and criteria used in the establishment of these standards are also subject to constant review.

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*Chapter 3*

# SOURCES OF ATMOSPHERIC POLLUTION AND MEASURES FOR THEIR CONTROL

## THE MAIN SOURCES OF AIR POLLUTION AND OVERALL CONTROL MEASURES

According to the definition by V. A. Rjazanov (1961a), air pollution can tentatively be regarded as those admixtures in the atmosphere that are formed not as a result of elemental natural processes but as a result of human activities. In the course of his productive activities, man subjects natural materials to mechanical, physical, chemical or biological processing and as a result large quantities of various substances are discharged into the air in the form of gases or fumes, or are heterogeneously dispersed in dust, smoke, or mists.

One of the major sources of air pollution until recent years was the combustion of fuel and the discharge into the atmosphere of sulfur oxides, soot, and ash. The main ingredient of smoke is ash, and the amount discharged depends on the ash content of the fuel and the method of combustion.

The ash content depends on the mineral content of the coal and the amount of dirt mixed with it. The first component cannot be removed but represents only a small proportion of the total ash; the second forms the bulk of the foreign matter and can be removed by prior sorting of the coal.

The higher the ash content of the coal, the lower the quality and calorific value. These is wide variation in the ash content of different types of fuel. Thus, the ash content of Donets AP anthracite is 4.5%, of brown coal from the Moscow area 23.6%, of Kizel coal 28.5%, and of shale 50% and over.

In the absence of air pollution control devices, the amount of ash discharged depends not only on the ash content of the fuel but also on the design of the furnace. Data on ash production in relation to the type of fuel and design of the furnace are given in Table 11.

TABLE 11. PERCENTAGE OF ASH DISCHARGED INTO THE ATMOSPHERE IN RELATION TO MODE OF COMBUSTION AND QUALITY OF FUEL *

| Type of furnace | Type of fuel | Ash discharged into atmosphere (%) |
|---|---|---|
| Pulverized-coal furnaces with solid clinker disposal: | | |
| Front-fired | Anthracite and brown coal | 85 |
| Tangentially-fired | Black and brown coal | 93 |
| Direct-fired with pulverized fuel from a shaft mill | Brown coal | 85 |
| | Shale | 65 |
| | Peat briquettes | 97 |
| Pulverized-coal furnaces with hydraulic clinker disposal: | | |
| Single-chambered | Coal | 60-70 |
| Twin-chambered | Coal | 30-40 |
| Cyclone furnaces | Coal | 10-15 |
| Fire-grate furnaces | All forms of fuel | 20-30 |

* Data from Zalogin & Šuher (1954).

The ash discharged per kg of "standard fuel" with a calorific value of 7000 calories is as follows:

| | |
|---|---|
| Donets AP coal: | 43 g/kg |
| Donets AS coal: | 192 g/kg |
| Moscow coal (coalfield K): | 340 g/kg |
| Kashpir shale: | 1633 g/kg |

If a boiler of a given capacity is heated with shale instead of Moscow coal, therefore, the absolute amount of ash discharged increases almost fivefold.

The amount of sulfur dioxide discharged into the atmosphere in fuel combustion depends on the sulfur content of the fuel (see Table 12).

TABLE 12. CONCENTRATION OF SULFUR DIOXIDE IN FLUE GASES

| Type of fuel | Sulfur content (%) | Sulfur dioxide discharged (g/kg) |
|---|---|---|
| Kuznetsk coal | 0.4 | 8 |
| Donets coal | 1.8 | 36 |
| Moscow coal | 2.6 | 52 |
| Kizel coal | 5.1 | 102 |
| Kashpir shale | 3.4 | 68 |

The massive pollution of the air above some towns is caused by the utilization of low-grade fuels, but in recent years the situation in the USSR has changed considerably. Radical steps have been taken to eliminate smoky atmospheres. For the supply of heat, domestic grates and small boiler-rooms have given way to heating-and-power plants. At these plants the coal-burning process has been rationalized and the efficiency of furnaces increased. Incomplete combustion has been reduced. Ash arresters with a high collection efficiency have been installed, regulations limiting the sulfur content of fuel have been introduced, and, most important of all, mineral fuel has been replaced by natural gas. For example, in the city of Moscow as a whole, the mean annual index of sulfur dioxide pollution of the air fell from 0.74 to 0.25 mg/m$^3$ between 1956 and 1962, and the dust burden (dropped from 0.81 to 0.36 mg/m$^3$ in the same period. Changes in ash and sulfur dioxide emissions in Moscow since 1950 are shown in Table 13.

TABLE 13. CHANGES IN THE EMISSION OF ASH AND SULFUR DIOXIDE IN MOSCOW BY VARIOUS TYPES OF BOILER INSTALLATIONS (1950=100) *

| Year | Boiler rooms in electrical power stations | | Boiler rooms in industrial enterprises, apartment blocks, and municipal undertakings | | Total emission | |
|---|---|---|---|---|---|---|
| | Ash | Sulfur dioxide | Ash | Sulfur dioxide | Ash | Sulfur dioxide |
| 1950 | — | — | — | — | 100 | 100 |
| 1953 | 35 | 41 | 42 | 50 | 77 | 91 |
| 1954 | 11 | 36 | 35 | 46 | 46 | 82 |
| 1955 | 11.2 | 31.2 | 30.6 | 47.8 | 41.8 | 79 |
| 1956 | 6.1 | 25 | 34.4 | 50 | 40.5 | 75 |
| 1957 | 3 | 12 | 33 | 54 | 36 | 66 |
| 1959 | 3.8 | 10.5 | 20 | 47.5 | 23.8 | 58 |
| 1960 | 3.5 | 9 | 17.9 | 46 | 21.4 | 55 |
| 1961 | 3.4 | 9.3 | 17.6 | 42 | 21 | 51.3 |

* Data from Sokolovskij et al. (1965).

The sharpest decrease in ash emission in Moscow occurred in 1953-1954 as a result of the substitution of low-ash Donets coal for the high-ash coal from the Moscow coalfield. This reduction was particularly marked in the case of boiler installations in electrical power stations. Decreases in the amount of ash discharged by industrial, municipal and residential boiler installations, and also in sulfur dioxide emissions, were most marked in the years of conversion to gas. In Moscow, 800 industrial undertakings, over 100 000 domestic stoves, and about 1200 boiler installations in flats and municipal undertakings had been converted to the use of gas by 1962 (Table 14). A great deal of work was also done on piped heating installations.

TABLE 14. NUMBER OF INDUSTRIAL UNDERTAKINGS OPERATING ON GAS IN MOSCOW

| Year | No. of undertakings |
|---|---|
| 1958 | 262 |
| 1959 | 332 |
| 1960 | 525 |
| 1961 | 650 |
| 1962 | 800 |

* Reproduced from K. A. Buštueva (1971).

Conversion to gas in the USSR is very promising. The country has very rich reserves of natural gas and the amount extracted is increasing from year to year. The figure was 6 200 million $m^3$ in 1950, 47 200 million $m^3$ in 1960, and 129 200 million $m^3$ in 1965. The use of natural gas prevents the discharge into the atmosphere of large quantities of ash, soot, and sulfur dioxide, and is helping to eliminate air pollution in towns and industrial estates and to improve conditions of sanitation and hygiene for the population.

A very important measure in the campaign against smoky atmospheres in towns is the use of hydro-electric power. In 1957, hydro-electric power stations in the Soviet Union replaced 18 000 000 tons of "standard" fuel, and thereby prevented the discharge into the atmosphere of 2 880 000 tons of ash, 89 000 tons of soot, and 720 000 tons of sulfur dioxide.

Improvement in the quality of coal is also of great importance for preventing air pollution. Coal is treated at special coal-dressing plants at the pithead by a process that considerably reduces the content of sulfur and ash. The amount of dressed coal is increasing from year to year, and in 1955 over 25% of the coal used in the Soviet Union was treated in this way. Sulfur is found in coal in three forms: organic sulfur compounds, sulfates, and sulfides. Sulfates are discharged in the ash and do not contribute to the formation of sulfur dioxide, while the other forms are burnt in the furnace and converted to sulfur dioxide (and a small amount of sulfur trioxide). Organic sulfur is found in coal in constant but negligible quantities. Sulfides occur as pyrites or marcasite and the proportion is generally small. The wet-dressing of coal (washing) and the removal of pyrites reduce the amount of sulfur considerably.

The extension of central piped-heat systems, conversion to natural gas, and the electrification of industrial and domestic appliances have been carried out on a large scale and have reduced the smokiness of the atmosphere in centres of population in the Soviet Union. At the present time, industrial enterprises and motor transport are the main sources of air pollution. An estimate of the relative importance of each of the main branches of industry from the point of view of air pollution is given in Table 15. The principal sources of pollution are heating-and-power plants, ferrous and non-ferrous metallurgy, the petroleum and petrochemical industries, and motor transport.

TABLE 15. RELATIVE IMPORTANCE OF DIFFERENT SOURCES OF AIR POLLUTION, 1968-1969 *

| Source of air pollution | Share of total air pollution (%) |
|---|---|
| Heating-and-power plants | 27.0 |
| Iron and steel industry | 24.3 |
| Non-ferrous metallurgy | 10.5 |
| Chemical industry | 1.3 |
| Mineral oil production, petrochemical industry | 15.5 |
| Motor transport | 13.1 |
| Building materials industry | 8.1 |
| Others | 0.2 |

* Reproduced from K. A. Buštueva (1971).

Measures to control emissions from heat-and-power stations are mainly concentrated on smoke control, which is now a practical possibility. Undertakings in the iron and steel industry are important sources of pollution of the atmosphere with carbon monoxide, dust, and sulfur dioxide. An estimate of the amounts of pollutants discharged into the atmosphere by a modern metallurgical plant comprising 6 blast furnaces, each with a capacity of 1750 tons per day, and 16 open-hearth furnaces is given in Table 16. Recuperation of the blast-furnace gas sharply reduces the amount of carbon monoxide and dust discharged into the atmosphere.

In non-ferrous metallurgy, the main products are lead, zinc, copper, and tin. This branch of industry is a massive source of atmospheric pollution with dust and gases, some of which, such as arsenic, lead, and

TABLE 16. AMOUNTS OF POLLUTANTS DISCHARGED INTO THE ATMOSPHERE FROM A METALLURGICAL PLANT WITH NO FACILITIES FOR RECUPERATION OF BLAST-FURNACE GAS

| Ingredient | Amount discharged per 24 hours | | Total |
|---|---|---|---|
| | Blast-furnaces | Open-hearth furnaces | |
| Total amount of gas (million $m^3$) | 33 | 13 | 46 |
| Dust (tons) | 960 | 6 | 966 |
| Sulfur dioxide (tons) | 28 | 9 | 37 |
| Carbon monoxide (tons) | 12 000 | 200 | 12 200 |

mercury, are extremely toxic to man. Expansion of the production of light metals (aluminium, magnesium, and beryllium) has contributed to the pollution of the atmosphere with toxic fluorine compounds, 3,4-benzpyrene, and beryllium. The problem of controlling emissions from the metallurgical industry has also been largely solved. Fuller use of by-products and the recuperation of waste products are among the possible ways of reducing pollution. For example, the huge amounts of sulfur dioxide formed during metal smelting need not be discharged into the atmosphere; instead the gas, which is concentrated and fully suitable for sulfuric acid production, can be used as a basic material for sulfuric acid plants, which should be located near the smelting plants. Thus, metallurgical plants should form industrial complexes for the versatile utilization of all the products and by-products obtained from the raw material.

As was shown in Table 15, the oil-refining and petrochemical industry is responsible for over 15% of atmospheric pollution. This type of industry is characterized by contamination of the air with hydrocarbons, hydrogen sulfide, and malodorous gases (mercaptans, disulfides, thioethers, etc.). When the air in the vicinity of one oil refinery was analysed, concentrations over a range of 300–1180 mg/$m^3$ were found and, even at a height of 25–32 m, hydrocarbon concentrations ranged from 20–40 mg/$m^3$ (Bahusov & Samojlov, 1936). At a distance of 1200 m from a refinery, concentrations as high as 100 mg/$m^3$ were found and, at a distance of 1300-1450 m, concentrations of 90-100 mg/$m^3$ (Los' et al., 1950). In oilfields, the main measures for protecting the air against pollution are conversion to closed extraction methods, hermetic sealing of oil wells, and prohibition of the storage of oil in open tanks. In refineries, the oil is stabilized before being processed. Planning measures, such as the siting of refineries a long way away from centres of population, are also of great importance.

In addition to the main sources of atmospheric pollution discussed above, the building materials industry is a powerful source of pollution of the atmosphere with dust, sulfur dioxide, etc. Wastes from the chemical industry, although not often emitted on a massive scale, contain toxic substances that are extremely dangerous to the health of persons living in the neighbourhood of chemical plants.

The main pollutants of the atmosphere may be grouped as suspended solids (dust), sulfur dioxide, carbon monoxide, nitrogen oxides, and hydrocarbons. Their relative importance in total air pollution is roughly indicated in Table 17. Consequently, basic air pollution control measures must aim at reducing or completely eliminating these pollutants.

TABLE 17. RELATIVE IMPORTANCE OF INDIVIDUAL POLLUTANTS IN INDUSTRIAL WASTES DISCHARGED INTO THE ATMOSPHERE, 1968-1969 *

| Type of discharge | Percentage of total atmospheric pollution |
|---|---|
| Suspended matter (dust) | 28.8 |
| Sulfur dioxide | 27.0 |
| Carbon monoxide | 31.9 |
| Nitrogen oxides | 1.1 |
| Hydrocarbons | 10.7 |
| Other | 0.5 |

* Reproduced from K. A. Buštueva (1971).

However, natural processes also play a certain role in air pollution. Soil erosion, which turns fertile areas into lifeless deserts, is of particular importance. Experience in the Soviet Union has shown that pollution with natural dust need not be considered as inevitable. Extensive measures are being conducted to transform nature, and these in turn are radically altering the climate. The creation on a vast scale of lakes, reservoirs, watercourses, and inland seas, and the introduction of good crop rotation, irrigation, and water supply are changing the natural dustiness of the atmosphere. Extensive afforestation in semidesert and arid districts to combat soil erosion is another development that is helping greatly to control natural dust. Steps are being taken to reduce dust in urban areas by planting vegetation and making proper arrangements for the disposal of rubbish and the cleansing of courtyards, streets, and squares. A complete belt of forest and parkland round towns greatly helps to protect them from airborne dust.

In the control of atmospheric pollution with dust and gases of natural and artificial origin, a major part is played by the correct planning of towns and by amenity policies. One of the most important factors is the correct siting of industrial undertakings. The sanitary standards governing the planning of industrial undertakings in the USSR stipulate that, when a site is chosen for such an undertaking, an area for the housing of workers must be selected at the same time. The main sanitary requirement in the siting of industry in the Soviet Union is clear-cut functional zoning into residential and industrial districts, with the establishment of health protection zones between the boundaries of the industrial enterprises and those of the residential districts (see Annex 2). Industrial undertakings are sited to leeward of and downstream from the nearest residential district. In evaluating the wind direction for this purpose, planning decisions are based on the prevailing wind during the warm season, as found from mean monthly indices over a period of many years, since it is during the summer that people make most use of the open air for recreation, physical culture and sport, ventilation of dwellings, etc.

Local relief is also taken into account. Undertakings whose production processes lead to pollution of the surroundings with organic or chemical waste should be sited at a lower altitude than the residential areas so that the pollutants cannot be washed down to the latter with rain or snow. Undertakings whose main health hazards are gases, dusts, and fumes that pollute the air should be sited at a higher altitude, to permit better dilution of the wastes in the upper layers of the atmosphere and thereby reduce their concentration in the residential districts.

## MEASURES TO PURIFY AND REDUCE THE QUANTITY OF INDUSTRIAL WASTES DISCHARGED INTO THE ATMOSPHERE

The basic measures to eliminate or reduce the discharge of wastes into the atmosphere by industrial undertakings depend on rationalizing technological processes. The methods of rationalization can be summarized as follows:

(1) Harmful substances used in production should be replaced by less harmful substances. For example, benzine should be substituted whenever possible for benzene, ethyl alcohol for methyl alcohol, and non-toxic metals for lead.

(2) Harmful impurities should be removed from raw materials. Coal for example, should be dressed to remove its excess ash content. This not only improves the quality of the coal but reduces the amount of ash discharged into the atmosphere. Sulfur compounds should be removed from coal.

(3) Wet methods should be substituted for dry methods. For example, wet grinding of the raw material in cement manufacture results in considerably less discharge of dust from rotary kilns than does dry grinding. Hydraulic ash removal eliminates air pollution when ash is transported to dumps, etc.

(4) In dust-producing industrial processes, a very important role in the prevention of air pollution is played by mechanization, with the fitting of exhaust systems and devices for the cleansing of the extracted air. Every stage in the production process should be so mechanized, as any gap will quite often bring to nought the whole attempt to create healthier conditions. Loading, transport, and unloading should be mechanized, as well as the basic processes themselves. Bulk materials should be transferred from one installation to another by means of pipes, elevators, transporters, and screw conveyors, with closed hoods.

(5) Production processes accompanied by the evaporation and volatilization of liquid materials or the leakage of gases should be hermetically sealed and automated. Liquids and gases should be transported exclusively through closed, fully sealed pipes by means of pumps and compressors.

(6) Continuously operating equipment should be substituted for the intermittently operating variety. Many production processes are carried out on the batch principle, so that the machinery has to be stopped to unload the finished product and load the raw material. This system is unsuitable both from the economic and from the technical point of view. It is also unsuitable for hygienic reasons. In papermaking, for example, when the pulp-cooking process is completed, production has to be stopped for the pulp to be unloaded, and the excess unabsorbed gases are vented from the furnace into the atmosphere. When the pulp is being unloaded, the air in the workshop and in the surrounding area is inevitably polluted. In the continuous process the raw material is fed continously into the system and removed continuously in its processed form, so that there is no breakage of the seal at the end of the cycle and no need to discharge unspent gases into the atmosphere.

(7) The combined processing of raw materials should be introduced wherever possible. In this procedure the production process consists not only in obtaining the main product but also in processing the waste to obtain economically valuable materials. Thus, when copper is smelted the furnace gases contain a large quantity of sulfur dioxide, since the raw material is rich in sulfur. Usually smelters are designed only to produce copper, and huge amounts of sulfur dioxide are discharged into the atmosphere. In the combined method of processing, the sulfur dioxide obtained in roasting and smelting copper is fed to a sulfuric acid shop where it is transformed into sulfuric acid. In this way the dis-

charge of harmful gases is sharply reduced. Where combined processing is applied, little or no waste is discharged into the atmosphere, water, or soil.

(8) Solvents and other valuable substances should be recovered, i.e., trapped and returned to production instead of being discharged into the atmosphere. Benzine, for example, which is used as a solvent in rubber production and is usually discharged with the ventilation air in the form of fumes, should be trapped and recirculated.

These and other techniques of rationalizing production contribute in considerable measure to the reduction or elimination of atmospheric emissions. However, where it is impossible to design technological processes that do not produce waste gases containing dust, mists or fumes, special dust-arresting and gas-cleansing devices must be installed.

The sources of air pollution in an industrial undertaking can be divided into (*a*) the involuntary discharge of gases, due to leaks and holes in equipment and connexions, badly organized internal transport of dust-emitting or gas-evolving materials, stores of raw materials and finished products, ash dumps, sludge tanks, cinder pits, etc., and (*b*) the deliberate discharge of waste gases and ventilation air through smoke stacks, ventilation shafts, etc.

*Removal of suspended matter from gases*

The selection of devices to trap dust depends on the collection efficiency required under local conditions, the degree of dispersion of the dust, its capacity for aggregation, the danger of explosions, the temperature and humidity of the gases, and a number of other factors. Current methods for removing suspended matter from gases may be divided into four main types:

(1) mechanical or dry gas purification;
(2) wet gas purification;
(3) filtration;
(4) electrostatic precipitation.

*Dry gas purification*

The devices used for dry gas purification are based on the force of gravity (dust-settling chambers), the force of inertia (inertial separators and slotted dust arrestors), and centrifugal force (cyclone separators, multiple cyclone separators, rotary dust collectors, etc.). The devices are characterized by simplicity of design and ease of operation. However, their efficiency is low and they can be used only when the dust is not highly dispersed or as the first stage in purification. A very simple device for trapping dust is the dust chamber, in which dust settles under the force of gravity and through the slowing-down of the air current (Fig. 3). The efficiency of dust chambers is very low—roughly 40–50%. Such chambers are mainly used for the preliminary cleansing of furnace gases.

Inertial devices are much more efficient. An inertial device known as the KTIS dust separator has been proposed by the Bureau for the Standardization of Sanitary Engineering Equipment of the Ministry for Heavy Industry Construction (Fig. 4). This device consists of a

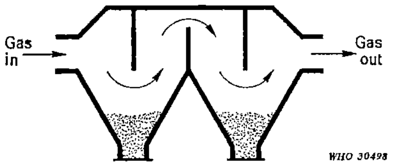


Fig. 3. Dust chamber

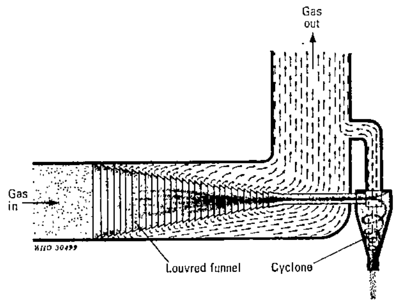


Fig. 4. KTIS inertial dust separator

cone, composed of rings of gradually decreasing size set into one another to leave a small clearance, thus forming an annular gap. Every ring represents the segment of a cone. The separator is installed inside a flue with its base towards the oncoming gas stream. The base fully blocks the cross-section of the flue, so that the dust-laden air is forced inside the cone. About 90% of the gas passes through the annular gaps between the elements of the separator, while the remainder, containing most of the dust, is directed towards the apex of the cone and through a connecting tube into a small cyclone fixed outside the flue, where it is purified. This inertial apparatus is a kind of dust concentrator.

For ash collection the All-Union Institute of Heat Engineering has suggested a special design of inertial separator, the VTI slotted ash-collector. This apparatus consists of two screens of angled plates, set inside a rectangular section of the flue. An aperture of irregular shape is formed between the individual plates that compose the screen. There are two models. In the first, the screens gradually converge towards the axis of the flue, where they form a suction aperture connected to a cyclone. In the second model, the screens diverge from the axis and form two suction apertures at the walls of the flue; through these apertures they are connected with two cyclones. In both cases, the screens divide the flue into two parts: an inlet chamber that the flue gases enter and an outlet chamber beyond the screens and connected to the smokestack. The mean efficiency of these ash collectors is relatively low, amounting to only 50–60%. They are very poor at collecting fine dust.

The State Institute for Research on Industrial and Sanitary Gas Cleaning (NIIOGaz) has developed special dust control devices consisting of groups of 4, 6 or 8 cyclones.

The NIIOGaz cyclone consists of a housing, cylindrical at the top and conical at the bottom, with rectangular gas inlet and outlet pipes placed at a tangent. At the top, the housing ends in a scroll cover, while below it is a hopper for the dust collected. As a result of the tangential flow of air and the volute shape of the housing cover, the dust-laden gas stream takes on a rotary motion. As a result, the dust particles are pressed by centrifugal force against the walls of the housing, move spirally downwards, and pass through the dust outlet into the hopper, whereas the dust-free gas rises again on reaching the lower half of the cyclone and is discharged through the outlet pipe.

This cyclone is an efficient piece of apparatus and is used for industrial and sanitary gas purification in the most varied industries. It ensures the trapping of 80–90% of the fly ash in flue gases from grate-fired furnaces.

A multiple cyclone consists of a number of individual cyclone elements grouped together in a single housing. Each cyclone element comprises a vertical cylinder becoming conical at the bottom and containing a central exhaust pipe for the upward venting of the cleaned gas. The dust-laden gas enters a gas distribution chamber and is directed downwards into the individual cyclone elements past deflectors that impart a swirling motion to it. The dust particles are pressed against the walls by centrifugal force and emerge from the bottom of the cyclone into a hopper. The dust-free gas passes back through the cyclone by way of the central exhaust pipe into a clean-gas chamber, whence it is discharged into the atmosphere or into another apparatus for further processing.

As many as 160 cyclone elements may be fitted into a multiple cyclone. Elements are manufactured in diameters of 100, 150, and 250 mm. Multiple cyclones are used to remove dry dust from the air and fly ash from flue gases. When pulverized fuel is burned, they have a collection efficiency for fly ash of 75–80%.

Various static and dynamic gas scrubbers are used for dry dust-collection in the USSR. The simplest static gas scrubber is the spray chamber, which consists of a hollow tower containing two rows of nozzles for the spraying of water (Fig. 5). The air enters at the bottom and rises to meet the spray of water. The dust is taken up by droplets of water and falls into the container of water in the bottom of the chamber. In this container the water is kept at a constant level, forming a gas-tight seal. The dirt (slime) that accumulates in the container is

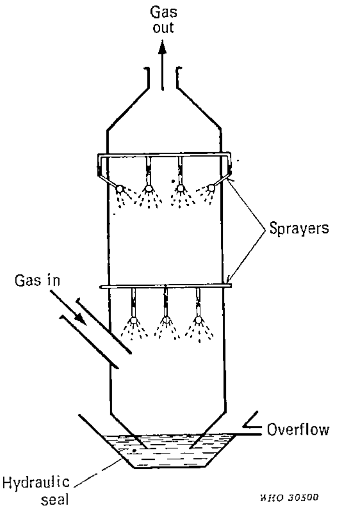


Fig. 5. Scrubber

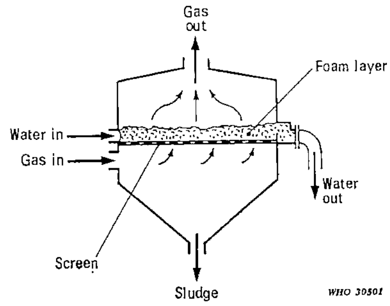


Fig. 6. Foam gas-washer

discharged through the overflow pipe. Spray chambers have a low collection efficiency of 50–60%. They are used for the preliminary cleaning of hot gases that need to be cooled and moistened, e.g., in metallurgical plants. A packed spray tower is more efficient. The packing is used to distribute a film of absorbent liquid over the greatest possible surface area, thus increasing the contact between the gas and the liquid.

*Wet gas purification*

Among wet dust-collection devices used in the Soviet Union are gravel filters, coke filters, water-film cyclones, foam gas-washers or dust-separators, and the VTI centrifugal scrubber.

The foam gas-washer developed at the Leningrad Technical Institute is a hollow chamber with one or more horizontal screens. The gas enters at the bottom of the chamber and passes through holes in the screen. Liquid is led on to the screen from above, and the gas bubbles through it to form a moving layer of foam in which there is a high degree of contact between the gas and liquid (Fig. 6).

When the gas stream passes through the screen at a velocity of 1.5–3.5 m/sec over the whole cross-section of the apparatus, a mobile foam is formed with no appreciable loss of liquid through the screen holes. At higher gas velocities there is a considerable loss through spray, and at lower velocities no foam is formed. Drawbacks to the use of foam gas-washers for purifying flue gas are corrosion of the metal due to the presence of sulfur oxides in the flue gas, spray loss, and a considerable reduction in gas temperature leading to corrosion of the flues. For the removal of dust from non-corroding gases, foam gas-washers have proved quite efficient, simple to make, and reliable in operation. They are being successfully used to remove lead dust from the ventilation air in printing works. Their collection efficiency is 85%.

The VTI centrifugal scrubber designed by the All-Union Heat Engineering Institute (VTI), is a vertical cylinder lined with red tiles and conical at the bottom. The gas is led into the apparatus through a tube fixed at a tangent to its inner surface. Nozzles fitted in the upper part of the apparatus produce a continuous film of water on the walls of the scrubber.

The gas to be purified enters the cylindrical part of the scrubber at a rate of about 20 m/sec and takes on a vigorous rotary motion. The dust contained in the gas is pressed by centrifugal force against the walls of the cylinder and trapped by the film of water flowing down the walls. The purified gas is discharged through the top of the scrubber and the water with the entrapped dust is led out of the apparatus through a hydraulic seal. While the dust is being trapped the water partially absorbs and cools the gas.

VTI centrifugal scrubbers effectively remove dust particles measuring over 1 μm. They are mainly used for cleaning flue gases, and their collection efficiency for fly-ash is 88–92% when pulverized fuel is being burnt.

*Filtration*

Gas may also be purified by filtering it through porous material such as fabric filters, which have been widely adopted in the Soviet Union in non-ferrous metallurgy, the cement industry, and flour-mills. Fabric filters may be of the envelope type or the tubular type, but in practice only the tubular bags are used. They are also called bag filters or beta filters.

A tubular bag filter (Fig. 7) comprises groups of fabric bag filters, one or more hoppers for collecting the dust, and a mechanism for shaking the bags. The gas to be purified passes through the filtration fabric in the bags, leaving the dust behind. From time to time each group of filters is removed from the gas supply in turn and the filters are cleaned by shaking and by means of a reverse jet, using a small amount of the dust-free gas. The dust is collected in hoppers, whence it is removed by an ordinary screw conveyor. Tubular filters are used in the industrial and sanitary purification of dry non-corrosive gases with

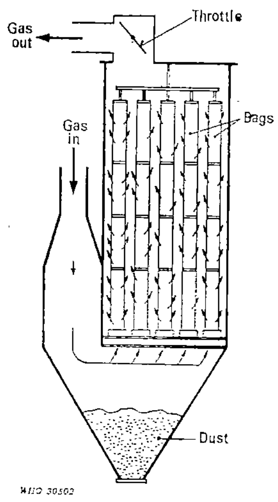


Fig. 7. Bag filter

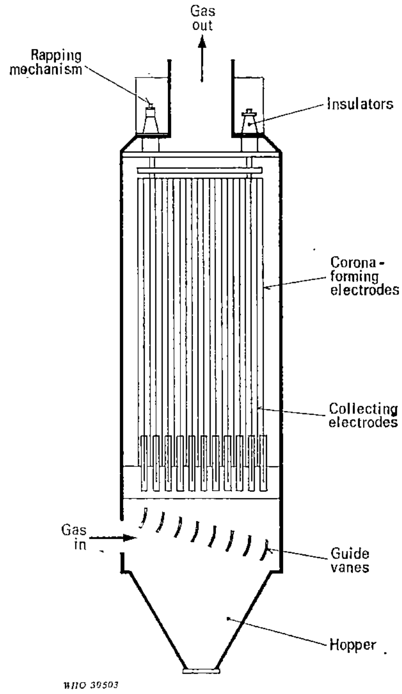


Fig. 8. Electrofilter

temperatures not exceeding 90 °C, mainly in cases where a high collection efficiency for fine dust is required. The efficiency of tubular bag filters ranges under various working conditions from 90 to 99%.

*Electrostatic precipitation*

The most efficient type of apparatus for trapping particulate matter is the electrostatic precipitator. It has been shown in practice that its use normally ensures almost complete collection of the particles suspended in the gas. Electrostatic gas purification is now being used in many branches of industry.

In an electrostatic precipitator the gas stream is ionized by corona-forming electrodes charged to a high negative voltage (up to 90 kV).

The dust particles or mist droplets also become electrically charged and are attracted to earthed collecting electrodes, which may take the form of pipes, plates, or a curtain of rods. Once the dust has settled on the electrodes, it is shaken off by means of a special rapping mechanism.

Electrostatic precipitators are used in various designs, specially adapted to the form of dust to be trapped and to manufacturing conditions. There are precipitators for separating ash from flue gas, for cleansing acid mists, and for trapping non-ferrous metal dust, cement dust, coal dust, pyrites cinder, etc.

As an example, Fig. 8 shows a plate smoke-precipitator with vertical gas flow. It consists of 2 or 4 parallel sections. The outer casing of the precipitator is made of sheet steel. Rows of plates suspended one above the other, and containing punched holes in the form of pockets to remove the entrapped ash from the stream of flue gas, serve as collecting electrodes. The ash that settles on the electrodes is shaken off automatically or by means of an electrically driven rapping mechanism. Wires of specially shaped cross-section are used as corona-forming electrodes.

On entering the precipitator, flue gases are distributed among the sections of the apparatus by means of guide vanes and pass through an electrical field. The collected ash is poured out of the pockets into hoppers, and then travels on a continuous conveyor through the dust gate into a hydraulic ash-removal system.

The electrical precipitator ensures 90–95% ash collection from flue gases derived from pulverized fuel. In a number of cases electrostatic precipitators are used as the second stage in a gas purifying installation, mechanical ash-separators (multiple cyclones or slotted ash-arrestors) being used for the first stage.

Another type of electrostatic precipitator is the plate precipitator with horizontal gas flow for smoke purification. This consists of two sections in a steel or ferroconcrete shell. The collecting electrodes are of the pocket type. Rapping is automatic, and the gas or electricity supply does not need to be switched off.

In horizontal flow precipitators the dust is carried away not in the opposite direction to the gas flow but at right angles to it. This makes it possible to pass the gas through two or three electrical fields in succession and considerably improves collection efficiency, which is as high as 98–99%.

To obtain a particularly high collection efficiency for particulate matter, the *Gazoočistka* Trust has designed the RION apparatus. This design obtains its effect by separating the processes of ionization and precipitation, which in ordinary precipitators occur simultaneously and on the same electrodes. The gases enter the apparatus from the side through a grid that retains large particles, and are then passed through the ionizer, which consists of vertical pipes with corona-forming electrodes placed between them. As a result of collision with the ions the dust particles acquire a negative charge. The gas is then passed through a system of collecting plates. These plates are of two kinds: one kind is riveted and fixed, while the other moves slowly in the gaps between the fixed plates. A potential difference is created between the plates as a result of which the charged dust particles settle on them. The plates are smeared with oil, which increases the efficiency of dust retention. The RION apparatus is intended for use when particularly careful cleansing of the air entering a room is required: in operating theatres, in photographic film factories, in some workshops in the pharmaceutical industry, etc.

*Removal of sulfur dioxide from gases*

One of the most widespread and hygienically important pollutants of the atmosphere is sulfur dioxide. There are many methods of removing sulfur dioxide from waste gases, such as extraction and subsequent conversion into sulfuric acid and salts of sulfuric and sulfurous acids, extraction followed by production of concentrated sulfur dioxide and by-products ("combined methods"), and extraction followed by production of concentrated sulfur dioxide without by-product formation ("cycling methods"). There are other techniques also.

The simplest method, i.e., the conversion of sulfur dioxide gas into weak sulfuric acid and salts, is to trap the sulfur dioxide in water. Sulfurous acid is then formed together with a certain quantity of sulfuric acid. Alkalis in the water partly combine with these acids, producing sulfites and sulfates. This method has not been widely applied, since the neutralization of the wash waters is complicated and expensive.

Another method is to trap sulfur dioxide with bases. This is done by washing the gas with a solution of alkalis until a mixture of sulfites and bisulfites is formed. The alkalis used are soda, ammonia, and lime. When sulfur dioxide gas is trapped in soda solution, sodium sulfite and sodium bisulfite are formed. The reaction takes place either in bubblers or in spray towers. This method again has not been widely applied, since the amounts of sodium salts of sulfurous acid required by the national economy are very small compared with the amount of sulfur dioxide discharged into the atmosphere.

The use of sulfur dioxide to obtain ammonium salts such as ammonium sulfate, an artificial nitrogenous fertilizer needed in large amounts for agriculture, is of somewhat wider significance. The sulfur dioxide is trapped in an ammonium sulfite solution to produce a mixture of sulfite and bisulfite. Subsequently ammonium sulfate is obtained from solutions of these salts, either by oxidation, as a result of blowing air through, or by auto-oxidation. Lime is the cheapest and most readily available base. The sulfur dioxide can be trapped in towers filled with limestone. The gas is fed into the tower at the bottom and passes through a layer of limestone to meet the water which is being sprayed over the packing from the top. The sulfurous acid obtained when sulfur dioxide is trapped with water reacts with the limestone packing to produce a solution of calcium bisulfite.

The second group of methods for removing sulfur dioxide from gas (combined methods) is based on further processing of the reaction products resulting from the trapping of the sulfur dioxide in order to produce concentrated sulfur dioxide gas, which finds a ready sale. The ammonia–sulfuric acid method, for example, is based on the fact that sulfur dioxide gas can be trapped by an ammonia solution. The resulting ammonium sulfite and bisulfite solution is broken down by sulfuric acid (Fig. 9). As a result, 100% sulfur dioxide gas and a

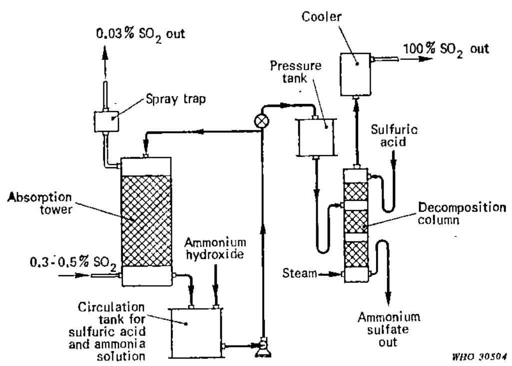


**Fig. 9. Ammonia – sulfuric acid method of removing sulfur dioxide**

solution of ammonium sulfate are obtained. The sulfur dioxide gas is dried and liquefied, and the ammonium sulfate sublimated. Collection efficiency ranges from 90 to 95%. Ammonium sulfate is a fertilizer for which there is a big demand. The sulfur dioxide can be sent for conversion into sulfuric acid. If sulfuric acid salts of ammonium are broken down with phosphoric acid, 100% sulfur dioxide gas is obtained, together with a still more valuable fertilizer, ammonium phosphate.

The combined methods also include a lime–sulfuric acid method, a zinc–sulfuric acid method, a nepheline method, and an alumina–lime–acid method.

The third group of methods for extracting sulfur dioxide comprises the "cycling" methods, i.e., those in which the absorbent is regenerated, giving off concentrated sulfur dioxide, and used again for cleaning further emissions of gas.

The methods in this group consist in concentrating the sulfur dioxide gas. For instance, water cycling is a method in which the sulfur dioxide is trapped in water and then steam-distilled. The solubility of sulfur dioxide in water is very low, and this method is therefore applicable only to comparatively concentrated gases, such as those encountered in non-ferrous metallurgy. An important objection, however, is the

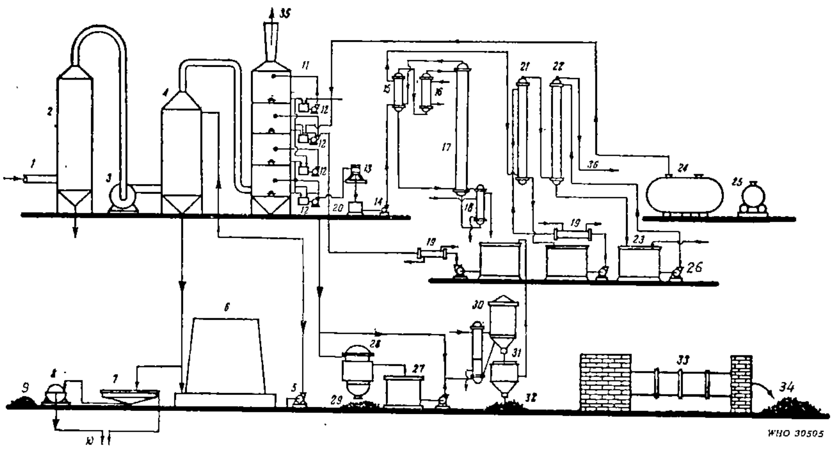

Fig. 10. Ammonia cycling method

1. Flue gas inlet. 2. Ash collector. 3. Gas pump. 4. Scrubber. 5. Pump. 6. Cooling tower. 7. Sedimentation tank. 8. Vacuum filter. 9. Ash sludge. 10. Clarified water. 11. Sulfur dioxide absorber. 12. Circulating pumps. 13. Pressure filter. 14. Pump to deliver solution for regeneration. 15. Heat exchanger. 16. Heater. 17. Distillation column. 18. Boiler. 19. Cooler. 20. Collecting tank for filtered solution. 21. Ammonia scrubber. 22. Drying tower. 23. Sulfuric acid tank. 24. Ammonia storage tank. 25. Liquefied ammonia. 26. Acid pump. 27. Ammonium sulfate collector. 28. Autoclave. 29. Sulfur. 30. Evaporator. 31. Centrifuge. 32. Moist ammonium sulfate. 33. Ammonium sulfate drier. 34. Ammonium sulfate. 35. Clean gas outlet. 36. Outlet for 100% sulfur dioxide gas.

discharge of acid waste-water from the plant. Neutralization of the waste-water does not solve the problem, since the sulfites used for neutralization absorb large quantities of oxygen and upset the oxygen balance in the watercourse receiving the effluent.

Another method in this group is the ammonia cycling method, based on the absorption of sulfur dioxide in a solution of ammonium sulfite, and subsequent steam distillation. The solubility of sulfur dioxide in ammonium sulfite solution is roughly 800 times its solubility in water. The flue gases are first cleansed of ash in an electrostatic precipitator, then directed into packed scrubbers where the packing is under water spray (Fig. 10). There they are cooled to 30°C and the remainder of the ash is removed. The cooled gases enter the absorber, which is divided into four sections by horizontal partitions. The gases enter the bottom section, and rise through the second and third sections to the top section, whence they are discharged into the atmosphere. The three lower sections are sprayed with ammonium sulfite–bisulfite solution and serve to trap the sulfur dioxide gas. The top section is sprayed with water and serves to trap the ammonia fumes and splashes of the solution. The regenerated solution of ammonium sulfite–bisulfite with added ammonia is fed into the third section. The excess absorbent solution spills over into a head tank in the second section, and after spraying spills down into the head tank in the bottom section. After the bottom section has been sprayed, the solution goes back for regeneration. The course of absorption of sulfur dioxide gases in the absorber is as follows:

$$(NH_4)_2\,SO_3 + SO_2 + H_2O \rightleftharpoons 2\,NH_4HSO_3$$

When the ammonium sulfite absorbs the sulfur dioxide it is converted into ammonium bisulfite. The solution is regenerated by means of the reverse reaction: decomposition of ammonium bisulfite, with conversion to ammonium sulfite and the evolution of free sulfur dioxide. The regenerated solution passes through a surface heater, where it is heated to 80°C, and enters the distillation column where the sulfur dioxide is given off under vacuum. The regenerated solution returns to the absorber for spraying the third section, and the mixture of steam and gas enters the condensers. The water vapour condenses, and the sulfur dioxide, after drying with sulfuric acid, is liquefied and stored in tanks for despatch to consumers. The purification rate is 90%.

In addition there have been attempts to use other methods, such as the xylidine, dimethylaniline, sulfuric acid–alumina, and phosphoric acid–soda techniques, but these have not found practical application in industry.

In gas purification practical use is also made of a magnesite cycling method, in which the sulfur dioxide gas is absorbed in a scrubber sprayed with a suspension of magnesium hydroxide in water (Fig. 11).

As a result of the reaction between the sulfur dioxide and the absorbing solution, magnesium sulfite is formed. As the crystals of magnesium sulfite (with a slight admixture of magnesium sulfate) accumulate, some of the solution is taken out of circulation and passed into a classifier to remove the crystals. The magnesium sulfite is dried and roasted, which produces sulfur dioxide and magnesium oxide, the latter being returned to the system to produce fresh magnesium hydroxide suspension. This method is quite efficient, but the sulfur dioxide obtained has a concentration of only 13%, and it is therefore not economic to salvage it.

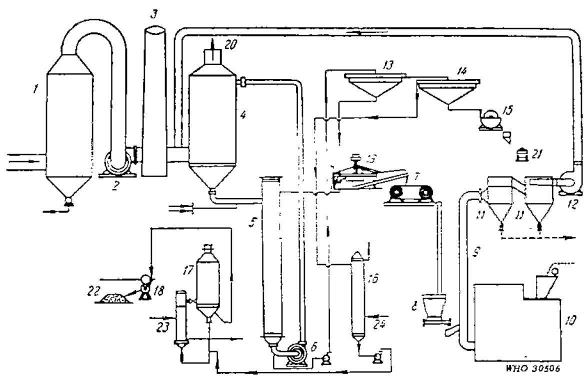

Fig. 11. Magnesite cycling method

1. Ash collector. 2. Gas pump. 3. Chimney. 4. Scrubber. 5. Crystallizer. 6. Pump. 7. Belt drier. 8. Hopper. 9. Drying funnel. 10. Roaster. 11. Cyclones. 12. Gas pump. 13. Sedimentation and crystallization tank. 14. Fly ash settling tank. 15. Drum vacuum filter. 16. Oxidizer. 17. Evaporation tower for magnesium sulfate. 18. Rollers. 19. Classifier. 20. Clean gas outlet. 21. Ash sludge. 22. Magnesium sulfate. 23. Steam supply. 24. Compressed air supply.

As is evident from the above description, some of the methods for removing sulfur dioxide from the gases emitted into the atmosphere by industrial undertakings are unprofitable or cumbersome, and preference is given to the magnesite and ammonia techniques. Technical and economic data on various methods employed at power stations using coal from the Moscow coalfield (which contains 3.1% sulfur) are shown in Table 18.

The ammonia cycling method has been successfully used to remove sulfur dioxide from flue gases, but it is suitable only for gases in which the concentration of sulfur dioxide by volume exceeds 0.3%. Methods of purification that do not aim at salvaging the sulfur, and are based on direct neutralization of the waste (e.g., lime and limestone methods) are very cumbersome and laborious; they require the transport of large amounts of raw materials, which makes them technically and economically unattractive.

*Carbon monoxide and its control*

Carbon monoxide is a product of the incomplete combustion of carbon-containing substances, and is the most widespread pollutant of the atmosphere, making up almost one-third in volume of all air pollution. Carbon monoxide is present in flue gases, blast-furnace gas, the exhaust gases of motor vehicles and aeroplane engines, etc. The burning of one ton of coal produces on average 20 kg of carbon monoxide. Blast-furnace gas contains up to 30% of carbon monoxide, and the amount

TABLE 18. TECHNICAL AND ECONOMIC DATA ON REMOVAL OF $SO_2$ FROM FLUE GASES BY VARIOUS METHODS, PER TON OF MOSCOW COAL BURNED *

| | Lime method | | Magnesite method | Ammonia method |
|---|---|---|---|---|
| | Using lime | Using limestone | | |
| Lime (85.7% CaO) | 48.7 kg | — | — | — |
| Limestone (94% $CaCO_3$) | — | 85.5 kg | — | — |
| Magnesite (85% MgO) | — | — | 5.5 kg | — |
| Ammonia (100% $NH_3$) | — | — | — | 4.4 kg |
| Fuel (coal from the Moscow coalfield) | — | — | 82 kg | — |
| Consumption of low-pressure steam (2 atm) | — | — | 30 kg | 330 kg |
| Water consumption | 0.83 $m^3$ | 0.9 $m^3$ | 4.8 $m^3$ | 9.1 $m^3$ |
| Electric power consumption | 14.5 kWh | 15.5 kWh | 18.8 kWh | 28 kWh |
| Degree of $SO_2$ removal | 98% | 85% | 98% | 90-94% |
| Liquid $SO_2$ (100%) | — | — | — | 40 kg |
| Ammonium sulfate | — | — | — | 6.4 kg |
| Sulfuric acid | — | — | 57.5 kg | — |
| Magnesium sulfate | — | — | 16.2 kg | — |
| Sludge (sulfite, calcium sulfate, ash) filtered off, with a moisture content of 45% | 248 kg | 295 kg | — | — |

* After Užov (1962).

discharged per ton of pig iron produced is 960 $m^3$, or 1.2 tons. Although the greater part of blast-furnace gas is burnt, the amount discharged is still significant.

In towns an important source of air pollution with carbon monoxide is motor transport. Exhaust gases from motor vehicles sometimes contain up to 10% of carbon monoxide, and the average concentration is 4–5% (Vol'fson, 1954).

The content of carbon monoxide in exhaust gases from carburettor engines depends on such factors as the technical condition of the engine and carburettor, the quality of the petrol used, and the amount of work performed by the engine. A ZIL-150 motor car whose engine is in good technical condition discharges on average 170 kg of carbon monoxide per ton of petrol used, but if the engine is in poor condition it discharges 600 kg. The Moskvich car discharges some 800 kg of carbon monoxide per ton of petrol (Nedogibčenko, 1958), the mass-produced GAZ-204 an average of 100 kg.

Water and rail transport, the smoke from which contains 3.5% and more of carbon monoxide, are also sources of air pollution.

Theoretically there are several chemical methods that could be used to control the discharge of carbon monoxide into the atmosphere, but in practice they have not found wide application. The only method in practical use is the combustion of carbon monoxide and its conversion into carbon dioxide. However, this is only possible and applicable when carbon monoxide concentrations are high, otherwise catalysts have to be used.

The basic measures to control carbon monoxide pollution of the air are linked with the rational planning and building of centres of population: they include the creation of a health-protection zone around industrial undertakings that emit carbon monoxide, the siting of residential districts away from main roads contaminated with motor exhaust gases and away from railways, and the electrification of urban railways.

Trolley buses, underground railways, and all forms of public transport are being widely developed in Soviet towns, and suburban railway services are being electrified, in order to reduce air pollution caused by exhaust gases from motor vehicles. Another important method of promoting clean air in the cities is the control of motor traffic. Transport using diesel engines has been banned in most towns from built-up areas, and goods traffic and transit lorries are made to use by-passes.

Carbon monoxide emissions can also be reduced by designing engines with a more modern process of fuel combustion, and by the development of devices to ensure the complete combustion of the carbon monoxide. Special neutralizers are now being introduced for fitting into cars.

*Removal of nitrogen oxides from gases*

To remove nitrogen oxides from gas NIIOGaz has developed effective methods of purification for use in industry. In some chemical plants, for instance, gases are washed with a caustic alkali solution to absorb nitrogen oxides. In the process useful products are formed (e.g., a solution of nitrate and nitrite), which are used in industrial processes. Sometimes cheaper alkaline suspensions of calcium oxide and magnesium oxide are used for separation. The content of nitrogen oxides in the scrubbed gas is 0.05%.

Alkaline scrubbing to remove nitrogen oxides is effective only when the gases have been pre-treated. In purifying waste gases from nitric acid plants it is essential to add to them concentrated nitrogen dioxide (100% $NO_2$). In some sulfuric acid plants in the USSR, e.g., where the tower method is employed, the acid itself is used in purifying the waste gases. The waste gases are washed in a packed scrubber with sulfuric acid at a concentration of at least 80%. In order to trap the excess nitrogen oxides, nitric acid ($HNO_3$) is added to the wash acid so that it will react with nitrogen oxide (NO) to form dinitrogen trioxide ($N_2O_3$). Waste gases from tower acid production are purified by the sulfuric acid method in a combined two-stage apparatus, the bottom part of which contains a packed scrubber-adsorber and the upper part a wet electrical precipitator (to trap the sulfuric acid mist and splashes). Practice has shown that this method disposes of all but 0.1–0.15% of the nitrogen oxides.

*Recovery of organic solvents*

By recovery is meant the removal of organic solvents from industrial wastes with a view to returning the solvents to the production process and reducing production losses. It is accompanied by measures to seal off the production processes and to equip all points where solvent fumes are given off with hoods and air extraction installations. Organic solvents are recovered by various methods:

(1) the condensation method, based on cooling the air-fume mixture to a temperature below that of the condensation point of the solvent fumes;

(2) the compression method, based on liquefaction of the solvent fumes by increasing the pressure with simultaneous cooling;

(3) the absorption method, based on absorption of the fumes in a liquid absorbent with subsequent desorption;

(4) the adsorption method, based on adsorbing the fumes on solid sorbents with subsequent desorption.

The first two methods have not found wide application, but the last two are widely used in Soviet industrial practice. The most common method of recuperation is the adsorbent method. The adsorbent mostly used is activated charcoal, followed by silica gel or other materials. The solvent fumes are led into a tank or scrubber filled with the adsorbent. The mixture of fumes and gases enters the bottom of the tank, passes through layers of adsorbent, and is discharged into the atmosphere. When the charcoal is saturated with the removed substances, steam is blown through the adsorber, which is thus regenerated. In the four-phase system of recuperation, each work cycle consists of the following stages:

(1) saturation of the activated charcoal with the solvent to be adsorbed;

(2) desorption of the adsorbed solvent;

(3) drying of the adsorber with hot air;

(4) cooling of the adsorber with cold air.

The two-stage method is now more often used (Serpionova, 1956). The mixture of fumes and air is passed through the adsorber hot, thus simultaneously drying the charcoal and ensuring sorption of the solvent fumes. After this a cold mixture of air and fumes is passed through, which cools down the charcoal as the solvent fumes are being adsorbed. When adsorption is complete, steam regeneration is carried out.

A large number of other widely known methods are used in industry for the removal of hydrogen sulfide, carbon disulfide, fluorine compounds, chlorine and its compounds, mercury fumes, and the fumes of phenol, lead and many other substances from waste gases. It is important to remember, however, that the main prerequisite for clean air is good engineering design of production processes, which prevents emissions into the atmosphere. This is why the sanitary services in the Soviet Union lay such stress on preventive surveillance. Such measures as hermetic sealing, gas scrubbing, dust collection, increases in the height of smoke-stacks, and the establishment of health-protection zones are only palliatives.

*Chapter 4*

# ORGANIZATION OF AIR POLLUTION CONTROL

## SANITARY SURVEILLANCE IN THE SOVIET UNION

One of the main advantages of the Soviet health system is the emphasis on prevention and the implementation of extensive measures to create healthier conditions in centres of population and to control air, water, and soil pollution. The main purpose of sanitary surveillance is to ensure that all elements of the environment—living, working, and recreational conditions, etc.—meet certain hygienic standards. One of the functions of the Ministry of Health of the USSR is to devise methods—through health legislation, hygienic standards, etc.—to create still healthier conditions in the Soviet Union.

Within the Ministry of Health of the USSR, and within the corresponding ministries in the Union and autonomous republics, there are boards of sanitation and epidemiology responsible for carrying out the functions of sanitary surveillance. The principal function of State sanitary surveillance in the USSR is (*a*) to ensure that measures are taken to eliminate or prevent pollution of the environment (water, soil, or air) by industrial or domestic wastes and to provide healthier living, working, and educational conditions for the population, and (*b*) to ensure the organization and implementation of measures to prevent disease.

With regard to State sanitary surveillance, the Soviet Ministry of Health:

(1) prepares and approves, within the framework of the existing laws of the USSR, decrees of the Presidium of the Supreme Soviet of the USSR, resolutions and orders of the Council of Ministers of the USSR, and hygienic standards and health and counter-epidemic regulations covering all aspects of hygiene and epidemiology and having mandatory force for Ministries, State committees, Government depart-

ments, enterprises, organizations, establishments, and private individuals; and

(2) ensures that the hygienic standards are observed both in the national design standards for construction and in the standards used for forecasting requirements and takes the necessary decisions in these matters.

The organs and establishments of the sanitary and epidemiological service ensure, on behalf of the State, that enterprises, establishments, organizations, and private individuals observe:

(1) the relevant laws and regulations of the USSR, the republics of the Union, and the autonomous republics and the decisions of the Council of Workers' Deputies;

(2) the prophylactic measures, hygienic standards, and health and counter-epidemic regulations, requirements, orders, and instructions of the Ministries of Health of the USSR, the republics of the Union, the autonomous republics, and the local health authorities;

(3) measures to prevent and eliminate occupational and communicable diseases and measures to prevent the entry and propagation in the USSR of quarantinable and other communicable diseases; and

(4) measures to prevent and eliminate the pollution by harmful industrial and domestic wastes of (*a*) surface and ground waters used for drinking, domestic, and recreational purposes, (*b*) the soil, and (*c*) the air.

The sanitary and epidemiological service also ensures that hygienic standards and health regulations are observed in (*a*) plans for future industrial development, (*b*) the design, construction, and reconstruction of enterprises, (*c*) the conversion or re-equipment of enterprises, municipal installations, or other premises, and (*d*) the planning and construction of population centres, housing, and public and other categories of buildings. It takes all necessary decisions in such matters. A decree relating to State sanitary surveillance in the USSR gives mandatory force to decisions of the sanitary and epidemiological service in regard to:

— projects for the planning and building of centres of population and the provision of amenities therein;

— projects for area planning and long-term plans for the siting of industry;

— design standards and projects for industrial, communal, hydraulic engineering, housing, transport and other forms of construction;

— projects for the allocation of plots of land for all forms of construction, and determination of the location of water-intake points and of the conditions under which effluents may be discharged;

— projects for the reconstruction, extension, conversion or re-equipment of industrial undertakings;

— draft State standards and technical specifications for new forms of raw materials, drinking-water, foodstuffs and industrial products that are being brought into production and might have a harmful effect on the health of the workers and the population, or might cause environmental pollution.

The organs of the sanitary and epidemiological service are entitled to prohibit, until such time as the requisite sanitary and counter-epidemic measures are carried out, the operation of (*a*) existing premises used for industrial, transport, agricultural, or communication purposes, (*b*) hydraulic engineering installations and public utilities, (*c*) public catering, trading, or other establishments, and (*d*) public, cultural, and recreational buildings and other premises. These powers also apply to ships, rolling stock, and aircraft found to be in an unsatisfactory sanitary condition or to represent a health risk.

In the case of a breach of the existing hygienic standards or health and counter-epidemic regulations, the sanitary and epidemiological service may halt the construction of buildings and installations and the entry into use of newly constructed, restored, or reconstructed housing, public, cultural, and recreational buildings, premises for industrial, transport, agricultural, or communications purposes, hydraulic engineering installations and public utilities, and public catering, trading, or other establishments and premises.

The official of the service may impose fines of 50–100 roubles on any party guilty of a breach of the health and counter-epidemic regulations. Where necessary, officials may institute legal proceedings against the guilty party.

It should be noted, however, that in the Soviet Union environmental pollution control, like epidemic control, is a matter for the whole State. The Central Committee of the Communist Party of the Soviet Union and the Council of Ministers of the USSR, in a decree dated 14 January 1960, instructed the councils of ministers in the republics and local soviets of workers' deputies to enlist the support of research and design institutes and trade union organizations in devising and carrying out measures to eliminate or prevent the pollution of watercourses, soil, and air in towns and industrial centres through industrial wastes and domestic effluents; to improve water-supply, sewage disposal, and town cleansing facilities; to make further improvements in working conditions and safety measures in industry and on State and collective farms; to ensure the observance of sanitary regulations in the food industry, public catering, and trade; and to make certain that sanitary standards and specifications are complied with in the design, building, and operation of industrial enterprises. This decree is a striking illustration of the anxiety of the State to provide good sanitary conditions and protect the health of the people.

Sanitary and epidemiological work in the USSR represents a system of public health improvement measures based on scientific and practical progress. Sanitary and epidemiological activities form part of the work of all medical establishments and all medical workers, whatever their specialty. To deal with specific problems, however, there is a need for the special knowledge of sanitary physicians and epidemiologists and for sanitary and epidemiological establishments. These activities, more than any other branch of medical work, depend on statistical studies of community health to provide a basis for practical sanitary measures and to verify their effectiveness. To make changes in the environment that are favourable to human life, and to create healthy living, nutritional and working conditions, a knowledge of the physical, chemical, and biological aspects of environmental factors is needed. A sanitary physician, therefore, makes constant use of laboratory tests —physical, chemical, bacteriological, and biological—for detecting harmful factors and preventing their occurrence. It is of great importance for the sanitary physician to learn to make an expert assessment of sanitary and hygienic conditions and to evaluate projects, plans, and drawings. To study the effect of individual factors on the organism, it is also necessary to carry out experiments on animals or to conduct suitable clinical or physiological investigations. Physiological methods are widely used in practical sanitary work. It is not only the immediate material factors in the environment or in working and living conditions that are of decisive importance in creating hygienic conditions, but also people's behaviour. Consequently the people themselves must play a constant part in carrying out health-giving measures. This is why hygiene training, health education, and voluntary sanitary work are widely organized. In his sanitation and epidemic-control work, the doctor relies on hygiene standards laid down by the State and on health legislation, which gives hygiene requirements the force of law.

The hygiene standards and the sanitary and epidemiological regulations drawn up and adopted by the Ministry of Health of the USSR are legally binding on all ministries, State committees, branches of the administration, undertakings, organizations, establishments, and private citizens.

The concept of "sanitary and epidemiological work" comprises:

(1) State sanitary and health-improvement measures,
(2) health legislation,
(3) the practical activities of the bodies and establishments of the sanitary and epidemiological service and of the national health services,
(4) scientific research,
(5) the training of specialists in hygiene and epidemiology,
(6) participation of the public in the organization and implementation of mass health-promoting and preventive measures, and
(7) a system of measures to spread knowledge of medicine and hygiene among the population.

This work is mainly carried out by the sanitary and epidemiological ("sanepid") centre, which is a complex medical establishment responsible for all forms of sanitation and epidemic control in a *rayon*, town, *oblast*, *kraj*, or republic.[1] The structure of a *rayon* sanepid centre in a rural area is represented in Fig. 12.

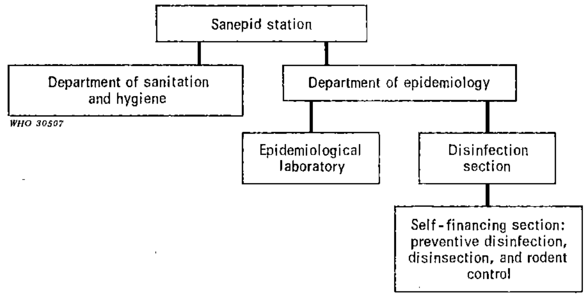


Fig. 12. Structure of *rayon* sanepid stations in rural areas

The department of sanitation and hygiene in the sanepid centre of a rural *rayon* carries out all measures for the protection of the environment in the *rayon*, including the prevention of air pollution. On its staff there is a sanitarian specializing in problems of hygiene. The structure of *oblast* (*kraj*) sanepid centres is shown in Fig. 13.

In *oblast* (*kraj*) sanepid centres, just as in urban centres, it is the department of sanitation and hygiene with its various special sections that is mainly responsible for carrying out sanitary measures. The

[1] Each constituent republic of the USSR is divided into *oblasts*, and each *oblast* into *rayons*. For historical reasons certain large administrative divisions still bear the name of *kraj*. Administratively a *kraj* is the equivalent of an *oblast* and is similarly divided into *rayons*.

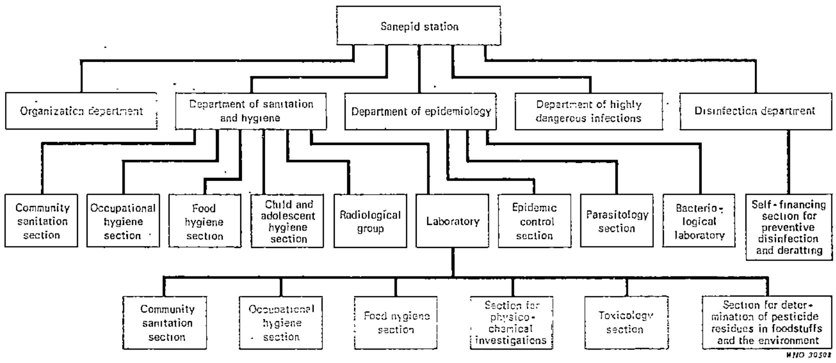


**Fig. 13. Structure of *oblast* (*kraj*) sanepid stations**

community sanitation section and the corresponding laboratory include a unit for air pollution control, although in some cases this work is carried out by the occupational hygiene section. In some towns, particularly in Moscow, a special unit for air pollution control has been set up within the department of general and community sanitation (Fig. 14), and the sanepid centres of urban *rayons* have sanitarians on their staffs who are responsible for air pollution control.

Sanepid centres are placed in different categories according to the number of people they serve, and the staffing and structure depend on the category (Aniskevič et al., 1970). The specialized staff in a department of sanitation and hygiene is made up basically of sanitary physicians specializing in various aspects of sanitation and of assistant sanitary physicians. In 1970, the USSR had 4 619 sanitation and epidemiological centres with a staff of 40 474 physicians engaged on sanitary and counter-epidemic work. Of this number, over 10 000 were sanitary physicians.

Sanitary inspection and surveillance are comprehensive in scope. Two types or surveillance are distinguished: preventive and routine. Preventive sanitary surveillance is carried out in cases of new construction or radical reconstruction. The sanitarian evaluates the building plans and projects from the point of view of hygienic requirements, and during construction and fitting out of the building he checks that these requirements are complied with. He tries to prevent any possibility of infringement of sanitary regulations or the introduction of harmful factors. Preventive sanitary surveillance is carried out during the planning and construction of towns and centres of population and during the building of dwellings, schools (and other buildings used by children), public buildings, catering establishments, municipal undertakings, and

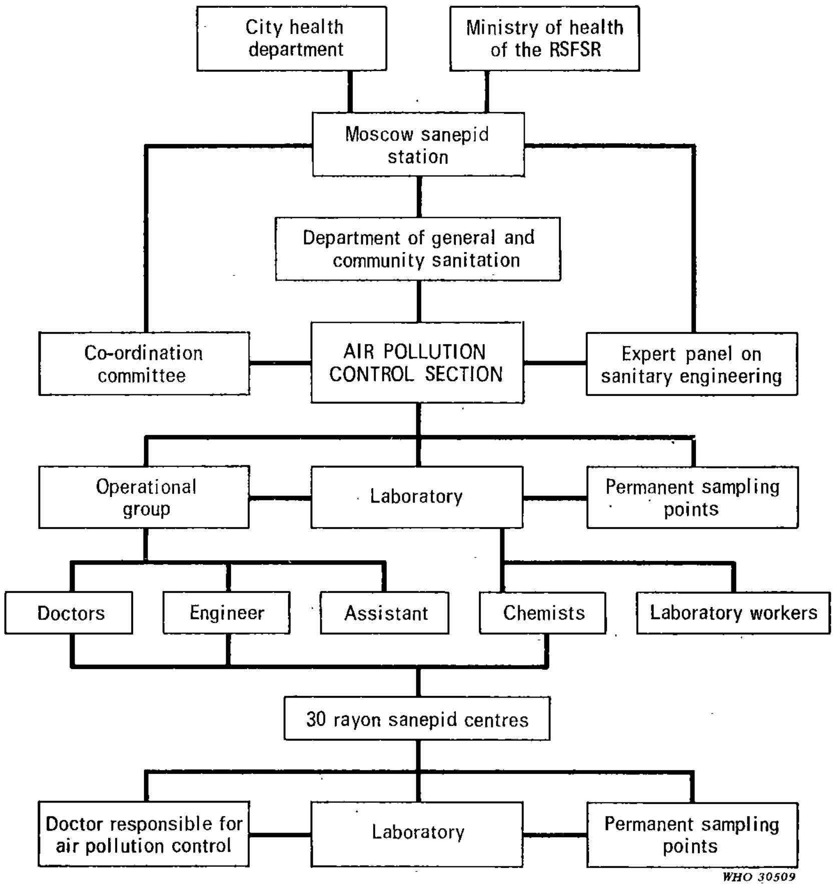


**Fig. 14. Structure of the Moscow Air Pollution Control Service**

industrial enterprises. The submission of projects and plans to the sanitary authorities for approval is mandatory. Preventive sanitary surveillance also covers engineering processes, as in industrial undertakings where a particular process may lead to pollution of the water, air, or soil in the locality, or have a harmful effect on the workers' health. In order to prevent such harmful effects, the protection of the atmosphere and watercourses from contamination with industrial wastes is guaranteed in mandatory rules governing the construction of industrial undertakings. It is one of the tasks of sanitary surveillance to see that these regulations are strictly observed. The aim of sanitary surveillance at the construction stage is to ensure compliance with the hygienic requirements incorporated in the plans and to make certain that the quality of the building materials meets the hygiene standards. Once construction is completed, the sanitarian, as a member of a State acceptance committee for the new undertaking, gives his opinion as to whether it may be brought into operation. To ensure wider preventive sanitary surveillance of particularly important and technically complex undertakings and measures, special sections for preventive sanitary surveillance have been set up in the sanepid centres of *oblasts* and large towns. These sections have on their staffs sanitarians specializing in such areas as air pollution control, industrial health, protection of watercourses from pollution with waste waters, and water-supply and sewerage systems.

Routine sanitary surveillance is carried out through regular checks, laboratory examinations, and periodic visits, on the basis of a prearranged plan. During the visits, any changes in the sanitary condition of the undertaking are noted. The immediate aim of these routine inspections is to discover any infringements of the sanitary regulations, to eliminate such infringements and prevent them from occurring again, and to improve the sanitary condition of the undertaking inspected.

The sanitarian organizes mass health education, systematically verifies whether assignments and proposals have been carried out, and applies disciplinary and penal measures prescribed by law to persons responsible for failure to observe sanitation and hygiene standards.

*Oblast, kraj* and republic sanepid centres are responsible for directing the activities of *rayon* and city centres. The activities of centres in *oblasts, krajs* and autonomous republics are directed by the boards of sanitation and epidemiology in the ministries of health of the Union republics. In addition to the sanepid centres, the Union republics and some *oblasts* and autonomous republics possess research institutes dealing with various branches of hygiene. The work of these institutes is concerned with organization, methods, and research, and they give practical assistance to the health authorities. The central executive body in the USSR for matters of sanitation is the Central Board of Sanitation and Epidemiology of the Ministry of Health of the USSR. The Chief Sanitarian of the USSR is an *ex officio* Deputy Minister of Health of the USSR, and similarly the chief sanitarians in the Union republics are also deputy ministers of health in those republics.

State sanitary surveillance is carried out by the organs and establishments of the sanitary and epidemiological service with extensive participation by the general population, the active members of trade unions, the active members of the Red Cross and Red Crescent societies, the public councils of sanitary and epidemiological establishments, curative and preventive establishments, and medical and other research societies and their branches.

On 13 August 1972, in a leading article on the sanitary service, the newspaper *Pravda* observed that the Soviet sanitary service, established nearly half a century previously, had gathered a rich store of experience in the medical surveillance of all branches of the economy and in the nationwide application of extensive prophylactic and counter-epidemic measures. The service was actively working for the continual improvement of the conditions of hygiene in which people live and work.

## TRAINING STAFF FOR THE SANITARY AND EPIDEMIOLOGICAL SERVICE

Training programmes for future sanitary surveillance staff, whether at university level or below it, have their own special requirements, determined by the general principles on which the sanitary service is founded and the tasks it has to perform.

The principal duties of the sanitary and epidemiological service include: regular surveillance of the sanitary situation (comprising all categories of sanitary inspection); the preparation of sanitary reports giving detailed accounts of the sanitary conditions prevailing at the various premises inspected; the performance of chemical, physical, toxicological, bacteriological, and other laboratory tests and the preparation of reviews of the general situation setting out decisions and requirements.

The performance of the highly complex duties involved in State sanitary surveillance and the organization of prophylactic and other sanitary measures require appropriately qualified sanitary physicians and feldscher sanitarians.

In the USSR, sanitary physicians, epidemiologists, bacteriologists, virologists, and other university-trained medical workers employed in the various branches of the sanitary and epidemiological service have followed a 6-year course of training at a faculty of sanitation and hygiene in one of the medical institutes.

Entrants to a medical institute must have completed 10 years of secondary schooling, or a course at middle-grade medical school, and have passed the entrance examinations.

In contrast to the practice in some other countries, physicians in the USSR specialize during their training and attend one of the following faculties: curative medicine, paediatrics, sanitation and hygiene, and stomatology.

All medical institutes and the medical faculties at some universities have common curricula, the curriculum for each type of faculty being approved by the Ministry of Health of the USSR and the Ministry of Higher and Secondary Specialized Education of the USSR, so ensuring that the same standard of instruction is provided at all the medical training establishments in the country.

The first 2 years of study give future physicians their preclinical training in general biology and medicine. Students study morbid anatomy and physiology, microbiology, and pharmacology and undergo preparatory courses in internal medicine and surgery.

It is generally in the third year that the differences in the curricula of the various faculties start to appear.

To some extent in the third year and increasingly in the fourth, fifth, and sixth years, students at faculties of sanitation and hygiene study the various branches of hygiene, i.e., occupational hygiene, community hygiene, school hygiene, food hygiene, epidemiology, social hygiene, public health administration, etc.

A large proportion of a medical student's time is spent in practical training, acting as assistant first to a nurse, later on to a middle-grade medical worker (nurse or feldscher) and finally during his fourth and fifth years to a physician. After completion of his fifth year, the medical student's practical work will be at the level of sanitary physician or epidemiologist.

At the end of the sixth year, students take the State examinations, and those who graduate successfully from a faculty of sanitation and hygiene receive the degree of doctor of sanitary medicine. The State assigns each newly qualified specialist to a post in accordance with interdepartmental plans for the employment of new graduates.

In recent years, some changes have taken place in the system of medical training in the USSR and thus also in the training of sanitary physicians. The social, scientific, and technical advances now taking place are accompanied not only by a further subdivision of the various branches of science but also by the forging of closer links between them. Various specializations have developed in medicine, and a reform of medical education has consequently become necessary (Petrovskij, 1972).

Thus, in view of the tasks now facing the health services, the quality of the training given to sanitary physicians and epidemiologists needs to be still further improved. The sanitary physican must have a wide training in the biological sciences and in general medicine, and a thorough grounding in the theory and practice of preventive medicine. To this end, the curriculum for sanitary physicians is being improved so as to integrate general and clinical subjects and hygiene as far as possible. This involves changes in teaching at the *subordinatur* stage followed by a period in residence in a seventh year of study (Ermakov & Mindlin, 1972).

F. G. Krotkov and G. I. Sidorenko (1969) also considered that sanitary physicians could not be adequately trained in 6 years and that they should receive a seventh year of study in residence. The further year spent in residence would enable the future sanitary physician to become thoroughly familiar with the assessment of the effects of a complex variety of environmental factors on man—an essential part of his functions and one that demands a knowledge of the principles of mathematics, physics, chemistry, statistics, and other subjects.

Of course, besides sanitary physicians, sanitary and epidemiological establishments employ engineers, physicists, chemists, biologists, and other specialists, and the need for technically qualified staff has risen considerably in all branches of the sanitary and epidemiological service. The staff of a sanepid centre now includes engineers specializing in such subjects as acoustics, removal of gas pollutants, water supply and sewage disposal, gas supply, heating and ventilation, industrial and public building, hydraulic engineering, and the planting of green zones.

Year by year the number of physicians increases, including those employed in the various branches and establishments of the sanitary and epidemiological service. Thus, in 1963, there were 33 685 physicians in the USSR working in the field of sanitation and epidemiology, while by 1970 this number had become 40 474. During the years 1966 to 1970 alone, 11 142 physicians qualified in sanitation and epidemiology, and a further 1 700 sanitary physicians are graduating every year from the 22 medical institutes with faculties of sanitation and hygiene.

A great deal of attention is paid in the Soviet Union to the further training of physicians. There are opportunities for sanitary physicians and epidemiologists to improve their qualifications at 13 institutes for advanced medical studies and at 14 faculties for advanced medical studies at the medical institutes.

The specialist and further training of physicians takes the form of study cycles lasting from 6 weeks to 3 or 4 months in various specialities such as air pollution control, the protection of reservoirs and water supplies from pollution, and town planning. Physicians following a course of further study receive their normal salary and are also given an allowance.

On completion of the study cycle, the physician receives a certificate that serves as a basis for promotion to the appropriate grade for his qualifications.

Since 1951, the Department of Community Hygiene at the Central Institute for Advanced Medical Studies, Moscow, has held a course in air pollution control given by Professor V.A. Rjazanov. Similar courses have been introduced as a regular feature of other institutes for advanced medical studies. Specialist and further training courses in air pollution control have become very popular among sanitary physicians as a whole and are attended not only by those specializing in air pollution control but also by town planning experts, industrial health physicians, etc.

The sanitary and epidemiological service cannot function effectively unless its various establishments have an adequate staff of middle-grade medical workers such as sanitary physicians' assistants and epidemiologists' assistants.

Feldscher sanitarians, sanitary physicians' assistants and laboratory technicians are trained in middle-grade medical schools for the appropriate specialty. The course of training lasts either 4 or 2½ years, depending on whether the student has completed 7–8 or 10 years of secondary schooling. The output of middle-grade medical workers is also rising every year, and at present 3 700 feldscher sanitarians and laboratory technicians graduate from middle-grade medical schools annually. F.G. Krotkov and G. I. Sidorenko (1969) have pointed out that for the best results the ratio of sanitary physicians to feldscher sanitarians should be 1 : 3.

Middle-grade medical workers (assistants) also take courses of further study from time to time to improve their qualifications.

Specialists in subjects other than medicine (engineering, chemistry, biology, law, physics, etc.) graduate from institutes or universities after a 5- or 5½-year course of study.

Team work between sanitary physicians and sanitary engineers and other nonmedical specialists in the various branches and establishments of the sanitary service facilitates the solution of technical problems.

## ORGANIZATION OF SURVEILLANCE

The purpose of sanitary surveillance in regard to air pollution by industrial wastes and effluents is to take prompt sanitary and technical measures to prevent, eliminate, or reduce pollution of the atmosphere with substances that might have a direct or indirect harmful effect on the health of the population. In carrying out this surveillance the sanitary authorities collaborate with the medical and sanitation departments in industrial enterprises to study morbidity among industrial and office workers, and with polyclinics and hospitals serving a particular area to study statistics on general morbidity, particularly among children; in this they also co-operate with institutes for research on sanitation and hygiene.

In the context of air pollution control, preventive sanitary surveillance comprises:

(1) registration of all sources of atmospheric pollution;

(2) registration of all undertakings planned, under construction, or being reconstructed that might become sources of air pollution;

(3) compilation of sanitary instructions for the prevention, elimination, or reduction of pollution;

(4) carrying out of regular laboratory checks on the pollution of the atmosphere at permanent sampling points;

(5) submission of plans for health-improvement measures concerning control of air pollution to ministries, branches of the administration, and economic organizations;

(6) study of projects for gas purification and other sanitary engineering measures providing protection against atmospheric pollution, and the publication of official conclusions regarding such projects.

(7) sanitary control of the implementation of approved projects to install sanitary engineering equipment for the prevention and control of air pollution.

By carrying out regular laboratory checks on the purity of the atmosphere, and thereby detecting sources of pollution, the sanitarian plays an active part in eliminating the causes of pollution.

Another, closely related aspect of the sanitarian's work on air-pollution control is routine sanitary inspection. The purpose of this is to eliminate or reduce pollution of the atmosphere with substances harmful to human health by organizing and carrying out efficient sanitary and health-improvement measures. The tasks of sanepid centres in regard to routine sanitary inspection for air pollution control include listing all gas-purifying and dust-separating installations, checking to ensure that they are operating correctly (see Annex 3), evaluating existing installations from the hygienic point of view, studying the extent and nature of air pollution by each undertaking, determining the relative importance of individual undertakings in the total air pollution of the area concerned, carrying out regular laboratory checks on the purity of the air, and making periodic sanitary inspections of industrial enterprises and other places that contaminate the atmosphere in centres of population.

The most important task of sanepid centres in the routine control of air purity is to study the effect of air pollution on public health. Information on this can be obtained by questioning the population about discomfort caused by dust, gas, unpleasant odours, etc. (see Annex 4); by recording cases of eye damage due to fly ash, grit, etc. (see Annex 5); by studying the records of the polyclinics and hospitals serving the area concerned; and by organizing special medical examinations of particular population groups (see Annex 6), especially children, in order to study the effect on human health of the various pollutants. For example, clinical X-ray examinations could be carried out to study the effect of exposure to free silicon dioxide.

A number of points are selected for regular monitoring of air purity in a particular area: one in the most polluted part of the industrial zone, one in a residential zone containing a few industrial undertakings, one in a residential zone with no local sources of industrial air pollution, and one in a control zone with a pure atmosphere free of industrial pollution. To study changes in air pollution at different times of day, two or three monitoring points should be set up in each zone, equipped with fixed installations for continuous air sampling and analysis. When control of air purity in a centre of population is first organized, it is recommended that two ingredients only should be determined: dust and sulfur dioxide. Checks on further ingredients for which maximum permissible concentrations have been established should be gradually introduced as the technique of observation and methods of investigation are mastered. All samples should be taken at human breathing height, in areas with a soil covering that does not produce dust, and a long way from local sources of air pollution, such as boiler-houses.

The duration of sampling, the rate of air aspiration when particular ingredients are being determined, and the sensitivity of the micromethods are prescribed in the official instructions issued by the Ministry of Health of the USSR (1963). According to these instructions, air samples should always be taken at permanent sampling points, the selection of which is very important. Before choosing the sampling points, a study should be made of the layout of the town, its future development plans, the siting of its industrial enterprises, residential areas, and major roads carrying a high density of vehicular and pedestrian traffic, the location of its green zones, etc. The wind rose for the town concerned is also determined on the basis of information supplied by the local meteorological station.

The permanent air sampling points must be so sited as to give a general picture of the quality of the air throughout the town, both in the centre and on the outskirts, whatever the particular activity in the various districts, and to allow the detection of any pollution of the air by industrial domestic, or transport wastes.

The samples must record not only the presence of air pollutants from local sources but also those that have diffused in from elsewhere. It is therefore recommended that, where possible, air sampling points be placed not less than 200 m from the chimneys of power stations, heat-and-power stations, or industrial enterprises, and located in open spaces with dust-free surfaces. Eight fixed sampling points are generally selected for a town and located at the centre and at various distances from the centre in a variety of directions, as follows:

Point No. 1 — in a residential area in the centre of town, Points Nos. 2 and 3 — in residential areas on the outskirts at opposite ends of the town, one with very smoky air and the other with relatively clean air,

Point No. 4 — in a place by a main road with a high density of vehicular and pedestrian traffic,

Point No. 5 — in an area where the air is heavily polluted with industrial wastes,

Point No. 6 — in the vicinity of a railway station,

Point No. 7 — in an open space on the premises of a factory,

Point No. 8 — the control point, placed outside the town in a zone with perfectly clean air uncontaminated with industrial wastes.

Air samples are taken daily at each sampling point at 8–10 a.m., when atmospheric convection and turbulent exchange are at a low level, and at 6–8 p.m., when there is a sharp fall in atmospheric turbulence. At the same time, meteorological observations are made at the sampling point (wind speed and direction, air temperature, humidity, etc.).

When analysing the information obtained, the sanitary and epidemiological service makes wide use of data supplied by the local stations of the Hydrometeorological Service of the USSR. Urban meteorological stations also record the degree of pollution of the air at their own observation points.

In processing the observational data, account must be taken of:

(1) the general conditions of hygiene prevailing at the main sources of urban air pollution,

(2) the monthly variations in atmospheric pollution at each sampling point,

(3) the effect of meteorological factors on air pollution,

(4) the qualitative composition of the urban atmospheric dust (dispersed chemical substances), and

(5) recommended measures for reducing air pollution.

Somewhat different recommendations apply to the organization and operation of a system for monitoring air quality in a population centre with a single source of industrial pollution. In this case, two lines of action are recommended—(*a*) the regular monitoring of air quality at permanent observation points in the town, and (*b*) the periodic testing of the zonal distribution of industrial emission by the taking of samples outside the town limits.

The recommended method of determining the zonal distribution of atmospheric pollutants is to take samples of the air at various distances downwind from the source of pollution (e.g., at 100 m, 500 m, 1 km, 2 km, 3 km or greater distances, depending on the strength of the emission, the height of the chimney, and the lie of the ground).

The results are processed to determine:

(1) the maximum one-time, mean, and minimum concentrations (in mg/m$^3$) of pollutants at various distances from the industrial enterprises,

(2) for each pollutant, the percentage of total samples (and the percentage of samples taken at each distance) in which the pollutant was found,

(3) the effect of meteorological factors on the degree of air pollution from industrial sources,

(4) the effect of various production conditions on the degree of air pollution,

(5) the effect of various operating conditions in gas purification and ash collection installations on the degree of air pollution,

(6) the specific pollutants found in the air of residential areas,

(7) the effect of air pollution on public hygiene and health,

(8) the need to review the size of the health-protection zones, and

(9) the measures required to reduce industrial pollution.

In the investigation of the zonal distribution of pollution, attention is also paid to the effect of industrial pollutants on vegetation (leaf damage, defoliation, damage to or destruction of trees, decrease in yields of fruit or vegetables, etc.).

To provide a basis for measures to control air pollution, various other objective indications of the effect of emissions on the living conditions of the population and of the harm caused to the national economy are used, such as damage to vegetation, the soiling of windows and buildings, and damage to roofs. Useful data can be obtained by studying the effect of emissions in causing soil pollution, particularly with toxic substances (lead, arsenic, fluorine, etc.), and the accumulation of such substances in vegetation. If these observations are carried out at the same time as measurements of air concentrations of these substances, the findings can be of great importance in checking maximum permissible concentrations of air pollutants and in providing further material on which to base such concentrations. If the help of the veterinary services is enlisted, observations can also be arranged on the condition and health of farm animals housed or grazed near large industrial enterprises discharging toxic compounds (see Annex 7). Sometimes the quality of milk and meat products obtained from such animals is also investigated, particularly for the presence of toxic substances that are known to pass into milk or to accumulate in the animal organism. Arrangements can also be made for observations on experimental animals kept in cages at different distances from the industrial undertakings concerned, and consequently exposed to different concentrations.

Parallel observations are often carried out on concentrations of particulate pollutants in the atmosphere and on the transparency of the air, which may be studied on the basis of the intensity of either the integrated radiation flux or the luminous or ultraviolet flux.

In every *oblast*, city, and (where necessary) *rayon* sanepid centre, there is a sanitarian responsible for organizing air pollution control. Sometimes the work is carried out by an expert in industrial health, responsible for supervision of the industrial enterprises that are often the source of air pollution. The organization of air pollution control in Moscow can be quoted as an example. The special section for air pollution control set up within the City Sanepid Centre in 1956 (see Fig. 14) is staffed by sanitarians, assistant sanitarians, and an engineer. In addition, a network of permanent sampling points has been set up, and air samples are regularly taken and analysed in order to determine the level of pollution. There are 30 *rayon* sanepid centres in Moscow, each of which has a sanitarian responsible for air pollution control, laboratories, and a permanent sampling point. The air pollution control section has close working links with the Moscow City Council, the Institute for the City of Moscow Master Plan, the Moscow Institute for Research on Hygiene (the F. F. Erisman Institute), technical organizations and institutes concerned with designing and inspecting purification equipment, and other bodies. General questions connected with sources of air pollution, the city's fuel supplies, the reduction of air pollution from motor exhaust gases, the establishment of health-protection zones, etc., are settled in consultation with the Moscow City Council. On the basis of data from the sanepid centres, priorities for the installation of purification plants in the city's industries are worked out. Work to determine the size of health-protection zones round industrial undertakings and to devise appropriate practical health-improvement measures in conformity with town-planning and sanitary requirements, is done in conjunction with the Institute for the City of Moscow Master Plan. The section also has links with the Moscow branch of the All-Russia Society for Nature Conservancy and the Planting of Greenery in Populated Centres. An *ad hoc* committee has been set up by the Chief Sanitarian of Moscow to co-ordinate air pollution control in the Moscow area. The committee comprises representatives of institutes of hygiene and technology, various branches of the municipal administration, ministries, the Academy of Municipal Services, and other organizations.

This co-operation between the Moscow sanitary and epidemiological authorities, the hydrometeorological authorities, the Institute for the City of Moscow Master Plan, and various research institutes has made it possible to control air pollution in the city.

Air pollution control is given high priority in the Moscow City Soviet of Workers' Deputies, which keeps the matter under constant review and supervises the implementation of its decisions.

Further examples can be given of the efforts made to improve air quality in other towns and republics of the USSR. Thus, the massive development of all branches of industry and the rapid growth of motor transport, coupled with an increase in the population density of industrial towns and population centres, have caused serious air pollution problems in the Georgian SSR. Studies were therefore undertaken by the air pollution control department and the Institute for Research on Sanitation and Hygiene (Šalamberidze & Pirchalava, 1970).

Research on air pollution control is closely linked with the activities of the sanitary service. In 1968 sanepid centres in the Republic carried out routine laboratory tests on air quality in the vicinity of 52 industrial plants. In large industrial centres, such as Tbilisi, Kutaisi, Rustava, and Batumi, the air is routinely sampled at permanent sampling points and analysed for dust, sulfur dioxide, and carbon monoxide content. Tests were also made to detect any motor vehicle exhaust gases in the air. In 1967, such tests were also carried out on the main roads in 9 towns.

The sanitary service carries out a great deal of preventive surveillance for the purpose of air pollution control. Plans for building or rebuilding industrial plant or air pollution control installations are examined as a matter of routine. Such studies and air quality monitoring data have been used in recent years as a basis for air pollution control legislation in the form of Government decrees, ministerial orders of the Ministry of Health of the Republic, and decisions of the executive committees of the local soviets. Each year the sanitary service reviews the implementation of the decrees and measures to reduce and eliminate air pollution and submits new proposals to the Government of the Republic for inclusion in the national economic plan. In recent years, at the request of the sanitary inspectorate, asphalt and concrete work and other industries have been moved outside the limits of several towns, including Sačere, Tbilisi, and Chakaja. The Georgian Government has issued a decree providing for evacuation of residents, schools, and hospitals from the health protection zones around ferro-alloy, lithopone, and cement works.

The sanitary service has supervised the conversion of several hundred industrial plants, domestic and municipal boiler installations, and domestic stoves and grates to natural gas fuel. From 1960, the year in which conversion stated, up to the present, over 135 000 gas stoves and 190 000 gas-fired water heaters have come into use in Tbilisi alone. During the same period, 153 industrial plants and 530 boiler installations have been converted to natural gas. In 1957, in 5 towns of the Republic and in the Abkhazian ASSR, 17 504 apartments, 24 children's establishments, and 32 other buildings were provided with gas. Laboratory tests have proved these measures to be effective. In Tbilisi and a number of other cities the dust and sulfur dioxide content of the air is within the maximum permissible concentrations.

Another example of air pollution control is the attempt to improve air quality in the towns and villages of the Ukrainian SSR (Kaljužnyj et al., 1968).

In an investigation of air quality, the A. N. Marzeev Institute of General and Community Sanitation, Kiev, has undertaken an experimental study of the biological effects of atmospheric pollutants, has started to establish limits for the concentration of such pollutants in the air, and—a task of great practical importance—has begun to determine on a scientific basis the size of health-protection zones for future industrial plants in the electrical power, carbon black, mining, cement, and other industries and for agricultural premises.

Using specially equipped laboratories, the Institute has also carried out research on the identification of carcinogenic substances in the wastes and effluents from the coke, metallurgical, oil, and mining industries and has tested, for blastomogenic properties, the wastes from such industries and from those manufacturing certain types of fuels and pesticides.

A great deal of useful research and practical work has been carried out in air pollution control in the Ukraine over many years by the sanitary service in close co-operation at all stages with a large number of bodies concerned with planning and economics. In addition to promoting a scientific approach to air pollution control, this work has given rise to important measures for the improvement of air quality in the industrial centres of the Republic. There has been a general acceptance and wide practical application of planning measures, the construction of air pollution control installations, conversion to gas in population centres, and conversion to gas of large industrial boiler plants and municipal and domestic boilers. Each year, the Ukrainian Government allocates a large sum for the installation of air pollution control equipment at existing enterprises and at those under construction or reconstruction.

The conversion of domestic boilers to gas and the installation of air pollution control equipment has considerably reduced air pollution in the towns concerned. Thus, in Dugansk, the dust content of the air has fallen by a factor of 24 and the sulfur dioxide content by a factor of four. After conversion of domestic boilers to gas in Donetsk, pollution of the air by dust and sulfur vapour in the central-heating period fell by half. When electrofilters were fitted at the Dramatorsk cement works and a number of other technical measures were taken, the amount of discharged dust was halved. Measures introduced at the Dneprodzeržinsk cement works reduced the amount of dust emitted from 100 tons a day in 1963 to 13–16 tons a day in 1965.

Similar examples of co-operation between sanepid centres and various research establishments, both medical and otherwise, for the improvement of air quality in population centres may be cited for many towns in the USSR.

*Chapter 5*

# INTERNATIONAL CO-OPERATION : COUNCIL FOR MUTUAL ECONOMIC ASSISTANCE

The Council for Mutual Economic Assistance (CMEA) has played a decisive role in the development of multilateral economic, scientific, and technological co-operation between socialist countries.

The decision to set up the CMEA was taken in January 1949 by the Governments of Bulgaria, Czechoslovakia, Hungary, Poland, Romania, and the USSR.

The CMEA was founded in the immediate postwar period in response to the urgent need to restore and rebuild the economics of the socialist countries and to make effective use of their productive capacities and resources.

Membership of the CMEA now includes Cuba, the German Democratic Republic, and Mongolia, while Yugoslavia takes part in the work of individual organs of the Council on equal terms with Member countries.

A strong network of economic, scientific, and technological links has been forged. A large number of research and construction design institutes have been set up to cover all fields of science and technology and all lines of research. They employ over a million highly qualified scientific staff (Petrov, 1971).

The complex programme to extend and improve co-operation between CMEA Members and to further their economic integration includes a wide-ranging plan for joint research, the exchange of scientific and technical information, joint consultations, and the preparation of long-term forecasts. One of the most important problems facing scientists of the socialist countries is the protection of nature and human health.

The successful development of the theory and practice of air pollution control in the USSR, the establishment of an economic basis for modern scientific investigations, and the facilities for training highly qualified specialists have led the countries belonging to the CMEA to co-ordinate their work on air pollution control.

The first co-ordinating conference of representative scientists from CMEA countries was held in Moscow in July 1963. Participants came from Bulgaria, Czechoslovakia, the German Democratic Republic, Poland, and the Soviet Union. This first conference dealt with the development of standardized methods and apparatus for determining air pollution, the study of the effect of air pollution on the environment, and the establishment of maximum permissible concentrations of air pollutants. It was recommended that the Institute of General and Community Sanitation of the Academy of Medical Sciences of the USSR (the A. N. Sysin Institute) in Moscow should act as a co-ordinating centre for research on these problems. At this conference the foundation was laid for international co-operation in finding a scientific basis for maximum permissible concentrations of air pollutants, studying morbidity due to air pollution, developing methods of research on pollutants, etc. (Rjazanov & Gofmekler, 1967).

The present status of air pollution control within the CMEA varies from one country to another, but co-ordination of the efforts of scientists in those countries working on the same problem is mutually advantageous and promises to be highly effective both scientifically and economically.

The rapid development of industry in Bulgaria has made air pollution a major problem in the cities and industrial areas. In 1963 the Bulgarian National Assembly passed a law on the prevention of air, water, and soil pollution. Much attention was paid to measures for preventing air pollution in residential districts. Environmental sanitation and healthy living and working conditions, i.e., the elimination or prevention of factors harmful for human health, are the main purpose of the measures carried out by the government and public bodies. In some industrial areas of Bulgaria, the air is polluted as a result of the building of industrial undertakings near populated centres, the absence of purification plants, and the use in electrical power stations and in ferrous and non-ferrous metallurgy of relatively poor raw materials with a high content of ash, sulfur, and other substances that pollute the air. Considerable pollution has been noted near to heat-and-power stations working on solid fuel, and metallurgical and cement plants. These undertakings discharge hundreds of tons of dust and gas into the atmosphere. Motor vehicles are also an important source of air pollution in large towns. Between 1963 and 1966, research in Sofia showed that, in winter, concentrations of sulfur dioxide in the air on some days reached 2.5 $mg/m^3$, and concentrations of sulfuric acid aerosols 0.47 $mg/m^3$, while the concentration of dust in the most highly polluted quarter reached 4.4 $mg/m^3$. As a result of the increase in motor transport, the content of carbon monoxide in the air of the city had risen sevenfold since 1957 (Kurčatova, Bykova & Argirova, 1967).

In view of the effect of the environment on health and disease among the population and the need for strict sanitary control of the environment, a State sanitary inspectorate was established at the Bulgarian Ministry of Health, with full powers to carry out environmental protection measures throughout the country. In areas where there are large industrial enterprises, institutes of hygiene and epidemiology are successfully carrying out research to determine the degree of air pollution and its effect on the people's health. The results of these investigations are being used in drawing up preventive programmes designed to create healthier conditions in these areas. The acute nature of the air pollution problem has led to the preparation of long-term programmes for cleaner air in the country's main industrial centres. These programmes are submitted for approval to the Council of Ministers of Bulgaria, which allocates the necessary financial resources. In 1967, the Council of Ministers adopted a programme designed to ensure cleaner air in Sofia and Pernik. Under the regulations in force in Bulgaria, factories may not be built if the plans do not provide for modern installations or systems for preventing air pollution. The State Sanitary Inspectorate plays a part in selecting the sites for industrial enterprises. All these measures are contributing to the solution of the air pollution problem and to the establishment of a healthier environment in populated areas.

In institutes for hygienic research and in sanepid centres a great deal of research is conducted on atmospheric pollution in towns and industrial estates, in order to provide a basis for establishing maximum permissible concentrations of pollutants and to study the link between such pollutants and morbidity. Bulgaria has officially adopted the Soviet maximum permissible concentrations for harmful substances in the air in populated areas.

In the German Democratic Republic, air pollution control has developed since the war to meet the needs resulting from the intensified development of industry. Attention has been mainly focused on the establishment of a basis for research on the links between atmospheric pollution and morbidity.

A great deal of attention is being paid in the German Democratic Republic to devising methods of investigating chemicals, including carcinogenic pollutants, in the air. Experimental research has been successfully conducted on the effect of atmospheric pollutants on plants and crops. Plants that can be recommended for growing in urban areas exposed to air pollution have been selected. The study of the effect of air pollution on the environment is combined with the study of public health questions and forestry problems.

In Poland a Clean Air Act adopted by the Council of Ministers in 1966 forms the legal basis for air pollution control. The Ministry of

Health is responsible for pollution control, and acts through the Chief Sanitary Inspector and the *voivodship*[1] sanepid centres.

In addition to the Clean Air Act, several decrees adopted in 1966-1967 dealt in detail with many of the basic factors in the problem of air pollution. These decrees, together with technical regulations based on them, lay down or recommend permissible air concentrations of some forms of pollutants, methods of measuring air pollutants, regulations for the siting of industrial enterprises in centres of population, and the duties of local authorities in regard to air pollution control. The width of health-protection zones round various types of undertaking in Poland has been laid down as follows: oil refineries, 500–1000 m; electrical power stations, 100–1000 m; cement works, 500–1000 m. A list has been approved covering more than 250 industrial undertakings and laying down the prescribed size of the health-protection zones.

A great deal of attention is paid in Poland to the correct siting of new undertakings. New factories and some existing ones are being equipped with dust-separating installations.

Research is being carried out to determine the links between the state of health of the population and air pollution. The Ministry of Health is receiving reports on the state of health of school-age children from various parts of the country where the metallurgical industry is concentrated. The Presidium of the Academy of Sciences has established an *ad hoc* committee to organize research on air pollution and its control. Regular measurements of air pollution are being carried out in the Katowice *voivodship*, in Warsaw, and in a number of other places.

In 1966-1967 all sources of air pollution in Poland were registered; the material collected has made it possible to distinguish the areas with the most serious air pollution, and efforts to reduce pollution will be concentrated in those areas. Under the Clean Air Act and a number of other decrees, all factories and mills must operate appropriate equipment for reducing the amount of pollutants in gases discharged into the atmosphere and must keep this equipment in good working order. Special attention is being paid to air pollution control in national parks, spas, and holiday areas, and the construction of industrial enterprises in such areas is forbidden. Special efforts are being made to reduce the discharge of soot and dust to a minimum. With this in view, a start has been made on the design and production of electrostatic separators. Polish scientists are paying a great deal of attention to the problem of reducing pollution of the air with smoke and gases, and most research carried out in the last 10 years has been designed to solve the

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[1] Poland is divided for administrative purposes into 17 *voivodships* and 5 cities of *voivodship* status.

problem of reducing pollution with sulfur, nitrogen oxides, dust, and soot. Methods for determining the amount of pollutants in the atmosphere have been worked out, and the system of laboratory control introduced throughout the country has produced good results. In all the *voivodships* and in the large cities, air pollution control services are in operation.

In Czechoslovakia, with its highly developed industry, air pollution is among the most important problems. The main sources of pollution are power stations, chemical and metallurgical plants, building materials factories, and opencast coal workings (Skovranek, 1967).

The main provisions for the control of air pollution in Czechoslovakia are contained in Law No. 20 dated 17 March 1966 on the protection of public health, and in Order No. 45, also dated 1966, concerning the establishment and preservation of healthy living conditions. This legislation defines the rights and duties of the public health authorities in regard to protection of the environment in the interests of public health. Law No. 35 of 1967, which prescribes measures for the control of air pollution, calls for technical inspection of control measures. Part 1 of the Law of 17 March 1966 [1] states:

> Every undertaking, co-operative, and other organization shall take, within its field of competence, all measures necessary for the establishment and preservation of healthy working and living conditions, and shall be responsible for the performance of this duty.

Paragraph 2 of Part 1 states:

> Healthy living conditions shall be established and preserved, in particular, by:
> (*a*) the protection of the hygienic condition of the air, water, soil and other constituents of the living environment, and in particular of urban areas, areas used for recreational purposes and as spas, dwellings and other buildings, areas accessible to the public and adjacent to undertakings, as well as public transport facilities, facilities for physical training, and establishments providing public services for the population.

A new programme is now being developed to protect the environment against pollution. Its principal features include:

(*a*) a changeover from coal of low calorific value to high-grade fuel with a low content of ash and sulfur;

(*b*) a gradual transition to engineering specifications that will ensure that little harmful waste is discharged;

(*c*) extension of the production of purification equipment, improvement in its installation, and stricter inspection;

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[1] An English translation of this Law has been published in *Int. Dig. Hlth Leg.*, 1967, **18**, 25-60.

(*d*) further research on equipment for sulfur removal and its installation in electrical power stations using coal that contains sulfur;

(*e*) further study of environmental conditions from the point of view of the atmospheric diffusion of emissions;

(*f*) the introduction of economic and technical incentives to encourage industrial undertakings to take into account not only the needs of production, but also the value of a clean environment for the whole of society.

A great deal of research on air pollution control is being conducted in Czechoslovakia. The Institute of Hygiene in Prague, which is the research establishment principally concerned with this problem, has been studying the effects of air pollution on public health for several years. The first data, obtained in 1958 in and around the city of Ostrava, clearly showed the link between a dust-laden and smoky atmosphere and conjunctivitis in children. In a highly polluted part of the city, conjunctivitis occurred almost 20 times more frequently than in a control locality with clean air.

In the town of Beroun, workers from the Institute of Hygiene established that in children under school age the highly smoke-laden atmosphere caused a decrease in haemoglobin level and in the colour index. Enlarged cervical lymph nodes—a reaction to constantly repeated inflammation of the respiratory passages—and changes in the X-ray lung picture were also found in children. For several years studies of air pollution have been carried out in Northern Bohemia, where, in a very smoky atmosphere, quite a high concentration of sulfur dioxide has been found.

The varied relief of the country, with a climate that prevents the diffusion of harmful substances and circulation of the air, the high density of population, the high degree of industrialization in some areas, and the system of fuel and power supply, based on the use of coal of low calorific value but with a high content of incombustible substances and sulfur, caused the amount of ash and sulfur dioxide in the air to increase between two and three times in some areas in the period 1957-1967. In recent years air pollution caused by exhaust gases has increased rapidly in the large cities as a result of the development of motor transport. In some industrial areas and large towns, air pollution is several times higher than the established sanitary and hygienic levels.

In Romania the problem of air pollution has become of prime importance during the last 20 years as a result of the development and diversification of industrial production. Air pollution arises almost entirely from industrial sources, the contribution of motor vehicles and other sources being very slight. The branches of industry causing most air pollution are the chemical industry, non-ferrous metallurgy, and the building-materials industry. The most frequently encountered pollutants are sulfur dioxide, dust, smoke, hydrogen sulfide, carbon monoxide, chlorine, fluorine, nitrogen oxides, etc.

In the majority of cases industrial undertakings are sited in areas with good wind conditions, at appropriate distances from centres of population. A number of enterprises, however, are sited in residential zones and in places where the relief is unfavourable; these cause air pollution. The total population exposed to pollution is roughly 450 000. So far the economic losses attributable to air pollution have not been accurately assessed. Studies carried out by the sanitary authorities have shown that air pollution affects crops and animals in areas where industrial wastes are discharged into the atmosphere. Particular types of damage to vegetation were noted as a result of exposure to emissions from chemical, metallurgical, and sulfuric acid plants and from cement factories. Cases of fluorosis were found in cattle and sheep whose fodder was obtained from an area exposed to emissions from a superphosphate fertilizer factory.

An analysis of physical development and morbidity among children living near a combined chemical and metallurgical plant that contaminated the air for a radius of 10 km with lead, copper, zinc, and sulfur dioxide, showed a higher incidence of defects in height and weight development, late ossification and rickets, anaemia, and acute respiratory infection in these children than in a control group not exposed to pollution. Ferrous metallurgy plants contaminate the air with dust, soot, and sulfur dioxide over a radius of several kilometres, and the concentration of these substances has been found to be many times greater than the maximum permissible level (20 times greater in the case of soot, and 14 times greater in the case of sulfur dioxide). In the zone exposed to pollution, higher-than-normal morbidity has been observed in the 0–15-year age group for rickets, inflammations of the eye, inflammatory diseases of the respiratory tract, and tonsillitis. When their electrical precipitators are out of action, cement factories discharge dust at levels reaching 3–4 $mg/m^3$ over a radius of many kilometres. A morbidity study among children living near cement factories before electrical precipitators were installed revealed that the incidence of several diseases was higher than in children not exposed to pollution: pulmonary tuberculosis 12–14 times higher, pneumonia 4.6–9.7 times higher, bronchial pneumonia 3.2–7 times higher, and bronchitis 2.7–4 times higher.

Present legislation on the control of air pollution in Romania is concerned mainly with the establishment of health-protection zones between sources of pollution and populated areas. The size of these zones depends on the nature and quantity of the pollutants discharged into the atmosphere. Maximum permissible concentrations (both momentary and 24-hour concentrations) have been established for the 10 pollutants most often encountered in the atmosphere. The legislation now in force stipulates that the siting of industrial undertakings must be co-ordinated with the planning of neighbouring localities, industrial plants being grouped together in functional zones. All new industrial sites must be approved by the sanitary authorities responsible for supervising measures designed to control air pollution and to prevent such pollution from affecting the health and comfort of the population. Investigations of air pollution and of morbidity among people exposed to it are carried out by standardized methods and working techniques devised by the Ministry of Health.

Within the CMEA, research co-ordination meetings on problems of air pollution have been held annually since 1963. At the second meeting in 1964, a start was made on the standardization of maximum permissible concentrations of air pollutants, and the delegation of specialists from the Soviet Union proposed that the list of such concentrations legally enforced in the USSR be adopted for international use. At the third meeting, in 1965, results of studies of the effect of atmospheric pollution on the environment, living conditions, and public health were reported and discussed. The fourth meeting in 1966 was concerned with proposals for the standardization of methods of investigating atmospheric pollution.

In 1967 a working plan was adopted for the co-ordination of research and technical investigation during the period 1968-1970. The main areas of research included in the plan were the establishment of a scientific basis for maximum permissible concentrations of air pollutants, the development of methods for determining such pollutants, the effect of air pollutants on the environment, living conditions, and public health, study of air pollution due to exhaust gases from motor vehicles, study of carcinogenic pollutants, and hygienic evaluation of the combined effect of different substances on the organism when ingested in different ways (in air, water, or foodstuffs). Extensive work has been carried out by the CMEA Scientific and Technical Council on the standardization of methods of determining air pollutants. Proposals were adopted regarding methods of determining the dust burden of the atmosphere per unit volume of air, and methods of determining a number of substances in air samples were standardized.

The seventh research co-ordination meeting in 1969 again dealt with the results of studies on atmospheric pollution, the standardization of methods of quantitative determination, and the prospects for scientific co-operation in this area. Delegates of each of the countries represented (Bulgaria, Czechoslovakia, German Democratic Republic, Poland, Romania, and USSR) gave information on research on air pollution control in their countries, and on progress being made with the co-ordination plan for 1969. The 1969 plan covered every aspect of the problem: the establishment of a scientific basis for maximum permissible concentrations of air pollutants, the development of methods of determining pollutants, study of the effects of air pollution on human health, research on the pollution of the atmosphere with motor exhaust gases, the problem of carcinogenic pollutants, etc.

The 1969 meeting discussed the need to standardize maximum permissible concentrations of air pollutants in the various countries. The approach to this problem adopted in the USSR was accepted as correct, and it was decided to begin standardization in 1970 (Sidorenko & Gofmekler, 1970 b).

The joint efforts of the CMEA countries to improve the control of air pollution are already bearing fruit. In Bulgaria, for example, a research programme to provide a scientific basis for establishing air purity standards has been in existence since 1967, and scientists from leading institutes of hygiene in Bulgaria are working in this field in Moscow, at the Institute of General and Community Sanitation of the Academy of Medical Sciences of the USSR (the A. N. Sysin Institute). The institutes of hygiene in Sofia are studying the effect on public health of atmospheric pollutants from a number of undertakings and are working out methods of investigating these pollutants.

In Poland, a planned study of the effect of motor-exhaust gases on the level of air pollution in towns was carried out in 1967.

Since 1966, specialists from Romania have been taking part in the research co-ordination meetings. The co-ordinated research plan for 1967 included a study by Romanian specialists of the combined effect of air pollutants and very important research projects on methods of comparative evaluation of techniques for determining sulfur dioxide and lead in the atmosphere.

The Institute of Hygiene in Prague has established a modern experimental base for toxicological investigations. A result of this was the inclusion in the plan for 1967 of extensive work to provide a scientific basis for maximum permissible concentrations of air pollutants under conditions of single and combined exposure. The effects of air pollution on the population, particularly children, occupy a prominent place in Czechoslovak research.

As a result of the co-ordination of research, the continuous exchange of opinions at annual meetings of the CMEA Scientific and Technical Council, meetings of chemists, the exchange of specialists, etc., considerable success has been achieved both in research and in sanitary practice. Progress in the standardization of methods of determining atmospheric pollutants is an indication of the results of co-operation. Methods have now been standardized for determining the most widely encountered air pollutants: sulfur dioxide, hydrogen sulfide, carbon disulfide, nitrogen dioxide, chlorine, arsenic, phenol, lead, formaldehyde, chromium, manganese, mineral acids, soot, ammonia, and nitrates. The Member countries are now studying the effects of air pollution on living conditions and health. Such research is necessary if the sanitary requirements that industry is called upon to meet are to be determined objectively.

Specialists in Bulgaria, Czechoslovakia, and the USSR are studying the effect of industrial emissions on human health, while specialists in the German Democratic Republic and Poland are concentrating mainly on the effect of industrial emissions on soil, forests, farm crops, etc. Scientists in the Soviet Union and Czechoslovakia have successfully developed a method for studying very slight biochemical shifts in the most vulnerable population group—children living in areas exposed to the harmful effects of industrial pollution. Co-operation between the CMEA countries has led to the development of new research topics, such as the mechanisms of the biological effects of atmospheric pollutants, the mechanisms of physicochemical transformations of harmful substances in the atmosphere, and possible new criteria of harmfulness for use in establishing maximum permissible concentrations (study of allergenic, mutagenic, embryotropic, and carcinogenic effects).

The exchange of information between countries on the research carried out on a particular problem not only makes it easier for scientists to use the results obtained, but also stimulates their own research. In defining the prospects for future co-operation between CMEA countries in research on air pollution, it has been pointed out (Sidorenko & Gofmekler, 1970 a) that there is an urgent need to devise and standardize methods of determining air pollutants; to intensify research to provide a scientific basis for hygienic standards and subsequently to adopt these standards within the CMEA; to develop standardized methods of studying the effect of air pollutants on public health, taking into account experience in CMEA member countries; to extend and improve theoretical research on the mechanisms of the biological effects of harmful substances; to study possible new criteria of harmfulness with a view to the establishment of hygienic standards; to found an international yearbook on air pollution control; to design automated analytical apparatus for determining atmospheric pollutants under practical and experimental conditions; to exchange specialists between countries on a wider scale, so that they can share information and experience; and to establish an international laboratory for the control of air pollution.

Another example of co-operation between CMEA Members on air pollution control is the co-ordination of research on the control of motor vehicle exhaust gases. In late 1971, the Second International Symposium on the Reduction of Urban Air Pollution by Motor Vehicle Exhaust Gases was held in Moscow. It was attended by experts from CMEA Member countries and Yugoslavia and by United Nations observers.

A paper was submitted by the German Democratic Republic on new standards for harmful substances in the exhaust gases of petrol engines and for the smoke content of diesel engines. Experts from Czechoslovakia reported on the development of a prototype electrically powered car for use in towns. Hungarian scientists discussed new instruments for analysing exhaust gases and new methods for evaluating the toxic risk from engines. Altogether 35 papers were read, many of them dealing with the medical and biological aspects of the control of exhaust gases.

The symposium supported the optimistic view of Soviet scientists that, provided measures to reduce the toxicity of exhaust gases are taken in time, the level of harmful substances in the air should henceforth decrease rather than increase despite the general rise in the number of motor vehicles, which by 1980 will have increased about 10 times and by the year 2000 about 40–50 times (Krivič, 1972).

The quality of the air on our planet depends on the concerted efforts of scientists and practical men throughout the world. There is no doubt that co-operation on air pollution control among the Members of the Council for Mutual Economic Assistance will strengthen and expand so as to promote a high standard of hygiene for their peoples in pursuance of the World Health Organization's aim—the attainment by all peoples of the highest possible level of health.

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*Annex 1*

# MAXIMUM PERMISSIBLE CONCENTRATIONS OF HARMFUL SUBSTANCES IN THE AIR OF POPULATION CENTRES

| Pollutant | Maximum permissible concentration ($mg/m^3$) | |
|---|---|---|
| | Maximum on one occasion | Average over 24 hours |
| 1. Nitrogen dioxide | 0.085 | 0.085 |
| 2. Nitric acid calculated as $HNO_3$ | 0.4 | 0.4 |
| calculated as hydrogen | 0.006 | 0.006 |
| 3. Acrolein | 0.03 | 0.03 |
| 4. α-Methylstyrene | 0.04 | 0.04 |
| 5. α-Naphthoquinone | 0.005 | 0.005 |
| 6. Amyl acetate | 0.10 | 0.10 |
| 7. Amylene | 1.5 | 1.5 |
| 8. Ammonia | 0.2 | 0.2 |
| 9. Aniline | 0.05 | 0.03 |
| 10. Acetaldehyde | 0.01 | 0.01 |
| 11. Acetone | 0.35 | 0.35 |
| 12. Acetophenone | 0.003 | 0.003 |
| 13. Benzene | 1.5 | 0.8 |
| 14. Benzine, from petroluem (low-sulfur fraction, calculated as C) | 5.0 | 1.5 |
| 15. Benzine, from shale (calculated as C) | 0.05 | 0.05 |
| 16. Butane | 200.0 | — |
| 17. Butyl acetate | 0.10 | 0.10 |
| 18. Butylene | 3.0 | 3.0 |
| 19. Butanol | 0.1 | — |
| 20. Tributyl triphosphate (butiphos) | 0.01 | 0.01 |
| 21. Valeric acid | 0.03 | 0.01 |
| 22. Vanadium pentoxide | — | 0.002 |
| 23. Vinyl acetate | 0.15 | 0.15 |
| 24. Hexamethylenediamine | 0.001 | 0.001 |
| 25. Hexachlorocyclohexane | 0.03 | 0.03 |
| 26. Divinyl | 3.0 | 1.0 |
| 27. Diketone | 0.007 | — |
| 28. Dimethylaniline | 0.0055 | 0.0055 |
| 29. Dimethyl sulfide | 0.08 | — |
| 30. Dimethylamine | 0.005 | 0.005 |
| 31. Dimethyl disulfide | 0.7 | — |
| 32. Dimethylformamide | 0.03 | 0.03 |
| 33. Dinyl (24% of diphenyl+76% of diphenyl oxide) | 0.01 | 0.01 |
| 34. Dichloroethane | 3.0 | 1.0 |
| 35. 2,3 Dichloro-1,4 naphthoquinone | 0.05 | 0.05 |
| 36. Diethylamine | 0.05 | 0.05 |
| 37. Isopropyl benzene | 0.014 | 0.014 |
| 38. Iso-octanol | 0.15 | — |
| 39. Isopropyl benzene hydroperoxide | 0.007 | 0.007 |
| 40. Propane-2-ol (isopropyl alcohol) | 0.6 | 0.6 |
| 41. Caprolactam (fumes, aerosol) | 0.06 | 0.06 |
| 42. Cáproic acid | 0.01 | 0.005 |
| 43. Carbophos | 0.015 | — |
| 44. Xylene | 0.2 | 0.2 |
| 45. Intrathion (M-81) | 0.001 | 0.001 |
| 46. Maleic anhydride (fumes, aerosol) | 0.2 | 0.05 |
| 47. Manganese and its compounds (calculated as $MnO_2$) | — | 0.01 |
| 48. Butyric acid | 0.015 | 0.01 |
| 49. 2,4,6-Trimethylaniline (mesidine) | 0.003 | 0.003 |
| 50. Methanol | 1.0 | 0.5 |
| 51. Parathion-methyl (metaphos) | 0.008 | — |
| 52. Metachlorophenyl isocyanate | 0.005 | 0.005 |
| 53. Methyl acrylate | 0.01 | 0.01 |
| 54. Methyl acetate | 0.07 | 0.07 |
| 55. Methyl mercaptan | $9 \times 10^{-6}$ | — |
| 56. Methyl methacrylate | 0.1 | 0.1 |
| 57. Monomethylaniline | 0.04 | 0.04 |
| 58. Monoethylamine | 0.01 | 0.01 |

| Pollutant | Maximum permissible concentration ($mg/m^3$) | |
|---|---|---|
| | Maximum on one occasion | Average over 24 hours |
| 59. Arsenic (inorganic compounds, except hydrogen arsenide, calculated as As) | — | 0.003 |
| 60. Naphthalene | 0.003 | 0.003 |
| 61. Nitrobenzene | 0.008 | 0.008 |
| 62. Nitrochlorobenzene (*o*- and *p*-) | — | 0.004 |
| 63. Parachloroaniline | 0.04 | 0.01 |
| 64. Parachlorophenyl isocyanate | 0.0015 | 0.0015 |
| 65. Pentane | 100.0 | 25.0 |
| 66. Pyridine | 0.08 | 0.08 |
| 67. Propylene | 3.0 | 3.0 |
| 68. Propanol | 0.3 | 0.3 |
| 69. Dust, non-toxic | 0.5 | 0.15 |
| 70. Mercury, metallic | — | 0.0003 |
| 71. Soot | 0.15 | 0.05 |
| 72. Lead and its compounds (except tetraethyl lead), calculated as Pb | — | 0.0007 |
| 73. Lead sulfide | — | 0.0017 |
| 74. Sulfuric acid | | |
| calculated as $H_2SO_4$ | 0.3 | 0.1 |
| calculated as hydrogen | 0.006 | 0.002 |
| 75. Sulfur dioxide | 0.5 | 0.05 |
| 76. Hydrogen sulfide | 0.008 | 0.008 |
| 77. Carbon disulfide | 0.03 | 0.005 |
| 78. Hydrogen cyanide | — | 0.01 |
| 79. Hydrochloric acid | | |
| calculated as HCl | 0.2 | 0.2 |
| calculated as hydrogen | 0.006 | 0.006 |
| 80. Styrene | 0.003 | 0.003 |
| 81. Tetrahydrofuran | 0.2 | 0.2 |
| 82. Thiophene | 0.6 | — |
| 83. Tolyl di-isocyanate | 0.05 | 0.02 |
| 84. Toluene | 0.6 | 0.6 |
| 85. Triethylamine | 0.14 | 0.14 |
| 86. Trichloroethylene | 4.0 | 1.0 |
| 87. Carbon monoxide | 3.0 | 1.0 |
| 88. Carbon tetrachloride | 4.0 | 2.0 |
| 89. Acetic acid | 0.2 | 0.06 |
| 90. Acetic anhydride | 0.1 | 0.03 |
| 91. Phenol | 0.01 | 0.01 |
| 92. Formaldehyde | 0.035 | 0.012 |
| 93. Phosphorus pentoxide | 0.15 | 0.05 |
| 94. Phthalic anhydride (fumes, aerosols) | 0.1 | 0.1 |
| 95. Fluorine compounds (calculated as F) | | |
| gaseous compounds ($HF$, $SiF_4$) | 0.02 | 0.005 |
| readily soluble inorganic fluorides ($NaF$, $Na_2SiF_6$) | 0.03 | 0.01 |
| sparingly soluble inorganic fluorides ($AlF_3$, $NaAlF_6$, $CaF_2$) | 0.2 | 0.03 |
| admixed with gaseous fluorine and fluorides | 0.03 | 0.01 |
| 96. Furfural | 0.05 | 0.05 |
| 97. Chlorine | 0.10 | 0.03 |
| 98. Chlorobenzene | 0.10 | 0.10 |
| 99. *m*-Chloroaniline | — | 0.01 |
| 100. Chloroprene | 0.10 | 0.10 |
| 101. Trichlorfon (chlorophos) | 0.04 | 0.02 |
| 102. Chlorotetracycline (for mixing with animal feed) | 0.05 | 0.05 |
| 103. Hexavalent chromium (calculated as $CrO_3$) | 0.0015 | 0.0015 |
| 104. Cyclohexane | 1.4 | 1.4 |
| 105. Cyclohexanol | 0.06 | 0.06 |
| 106. Cyclohexanone | 0.04 | — |
| 107. Cyclohexanone oxine | 0.1 | — |
| 108. Epichlorohydrin | 0.2 | 0.2 |
| 109. Ethanol | 5.0 | 5.0 |
| 110. Ethyl acetate | 0.1 | 0.1 |
| 111. Ethyl benzene | 0.02 | 0.02 |
| 112. Ethylene | 3.0 | 3.0 |
| 113. Ethylene oxide | 0.3 | 0.03 |
| 114. Ethylenimine | 0.001 | 0.001 |

**Notes**

1. When the following substances are simultaneously present in the atmosphere, their combined effect is equal to the sum of their individual effects:

(*a*) acetone and phenol
(*b*) valeric acid, caproic acid and butyric acid
(*c*) carbon dioxide and phenol
(*d*) carbon dioxide and nitrogen dioxide
(*e*) carbon dioxide and hydrogen fluoride
(*f*) carbon dioxide and sulfuric acid aerosol
(*g*) hydrogen sulfide and dinyl
(*h*) isopropylbenzene and isopropylbenzene hydroperoxide
(*i*) furfural, methanol, and ethanol
(*j*) cyclohexane and benzene
(*k*) strong mineral acids (sulfuric, hydrochloric and nitric) in terms of hydrogen ion concentrations
(*l*) ethylene, propylene, butylene and amylene
(*m*) 2,3 dichloro-1,4-naphthaquinone and 1,4-naphthaquinone

(*n*) acetic acid and acetic anhydride
(*o*) acetone and acetophenone
(*p*) benzene and acetophenone
(*q*) phenol and acetophenone
(*r*) sulfur dioxide, sulfur trioxide, ammonia, and nitrogen oxides

The sum of the ratios of the recorded concentrations to the maximum permissible concentrations should not exceed unity. This may be expressed mathematically by the following formula:

$$\frac{a}{m_1} + \frac{b}{m_2} + \frac{c}{m_3} \ldots \leq 1$$

where a, b, c ... are the recorded concentrations of the individual pollutants
$m_1$, $m_2$, $m_3$ ... are the corresponding maximum permissible concentrations for exposure to the single substances.

2. When the following substances are present simultaneously in the atmosphere the maximum permissible concentration for each substance separately continues to apply:
(*a*) hydrogen sulfide and carbon disulfide
(*b*) carbon monoxide and carbon dioxide
(c) phthalic anhydride, maleic anhydride and *a*-naphthaquinone.

3. When *p*-chlorophenyl isocyanate and *m*-chlorophenyl isocyanate are present simultaneously in the atmosphere, the criterion to be applied is that for the more toxic substance, i.e., *p*-chlorophenyl isocyanate. This is a temporary measure, to be used until a method is found of determining the substances separately.

*Annex 2*

# HEALTH PROTECTION ZONES[1] FOR INDUSTRIAL UNDERTAKINGS AND OTHER SOURCES OF ENVIRONMENTAL POLLUTION[2]

## INDUSTRIAL UNDERTAKINGS

Industrial undertakings shall, in accordance with their capacity and type of production, have the following health protection zones.

### The chemical industry

*Class I: Health protection zone 1000 m wide*

1. Production of nitrogen compounds (ammonia, nitric acid, and fertilizers).
2. Production of intermediate products of the aniline dye industry in the benzene and ether series (aniline derivatives, nitrobenzene, alkyl amines, phenol, etc.) where total output is over 1000 tons per year.
3. Production of intermediate products in the naphthalene and anthracene series (1-naphthalenol, anthraquinone, phthalic anhydride, etc.) in amounts exceeding 2000 tons per year.
4. Production of iron (III) bromide.
5. Production of paper pulp and hemi-cellulose by the sulfite, bisulfite, and monosulfite processes involving the combustion of sulfur or sulfur-containing materials; also production of paper pulp by the sulfate process.
6. Production of illuminating gas, water gas, or producer gas in amounts exceeding 50 000 $m^3$ per hour.
7. Plants for the underground gasification of coal.
8. Production of caustic soda and chlorine by electrolysis.
9. Production of rare metals by the chlorination process (titanomagnetite, etc.).
10. Production of artificial viscose fibre and cellophane.

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[1] When new technological processes are introduced, the width of the corresponding health protection zone must be determined in each particular case and approved by the Central Sanitary and Epidemiological Board of the Ministry of Health of the USSR and by the State Committee for Construction.

[2] Classified according to Sanitary Design Standards for Industrial Establishments (No. 245-71)

11. Production of concentrated mineral fertilizers.
12. Production of organic solvents and oils (benzene, toluene, xylene, naphthalenol, phenol, creosol, anthracene, phenanthrene, acridine, carbazole).
13. Production of arsenic and its inorganic compounds.
14. Production of petroleum gas in amounts exceeding 5000 $m^3$ per hour.
15. Oil refineries.[1]
16. Production of picric acid.
17. Production of hydrofluoric acid, calcium fluoride, hydrogen fluoride, and other fluorides.
18. Coal processing plants.
19. Plants for the chemical processing of peat.
20. Plants processing fuel shales.
21. Production of mercury.
22. Production of carbon black.
23. Production of sulfuric acid, fuming sulfuric acid, and sulfur dioxide.
24. Production of carbon disulfide.
25. Production of hydrochloric acid.
26. Production of superphosphate.
27. Production of phosphorus (yellow or red) and organophosphorus compounds (parathion, malathion, etc.).
28. Production of chlorinated and hydrochlorinated hydrocarbons.
29. Production of calcium carbide, acetylene from calcium carbide, and acetylene derivates.
30. Production of dimethyl terephthalate.
31. Production of caprolactam.
32. Production of cellulose nitrate fibre.
33. Synthesis of ethanol by the sulfuric acid process or by direct hydration, in plants with departments for concentrating sulfuric acid or carrying out desulfurization.
34. Production of artificial rubber.
35. Production of blowing agents for the rubber industry.
36. Production of amines (methylamine, dimethylamine, diethylamine, triethylamine, etc.).
37. Production of cyanides (calcium, sodium, copper, etc.), dicyanamide, calcium cyanamide).
38. Production of aminoheptanoic aminoundecanoic, aminononanoic, thiopentanoic, and isophthalic acids.
39. Production of sodium nitrite, hydrazine sulfate, hydrazine hydrate, ammonium sulfate, thionyl chloride, and ammonium carbonate.
40. Production of acetylene from hydrocarbon gases.
41. Production of dimethyl formamide.
42. Production of ethyl fluid.
43. Production of catalysts.

[1] Where oil with a sulfur content (by weight) of less than 0.5% is being refined, the health-protection zone is 500 m wide.

44. Production of products and intermediate products used in the synthesis of polymers.
45. Production of organosulfur dyes (sulfur black, etc.).
46. Production of hydrocyanic acid and its derivatives (acrylates, diisocyanates, etc.).
47. Production of beryllium.
48. Production of synthetic pharmaceuticals.
49. Synthesis of fatty acids and production of higher fatty alcohols by direct oxidation.
50. Mercaptan production and central plants for odorizing gas with mercaptans including facilities for odorant storage.
51. Potassium works.

*Class II: Health protection zone 500 m wide*

1. Production of urea and thiourea.
2. Natural-gas processing plants.
3. Production of niobium.
4. Production of tantalum.
5. Production of producer gas from coal and peat at a rate of 25 000-50 000 $m^3$ per hour.
6. Production and processing of natural tars and their residues (pitch, etc.).
7. Production of soda ash by the Solvay process in amounts exceeding 400 000 tons per year.
8. Synthesis of ethanol by the sulfuric acid process or by the direct hydration process in plants lacking a department for concentrating sulfuric acid or, in the case of the second process, a desulfurization installation.
9. Production of ammonium, potassium, sodium, and calcium nitrates.
10. Production of organic chemical reagents.
11. Production of plastics from cellulose esters.
12. Production of corundum.
13. Production of barium chloride with the use of hydrogen sulfide.
14. Industrial hydrogenation of fats (non-electrical process using hydrogen).
15. Production of synthetic fibres (e.g., acetate, polycaprolactam, polyesters, polyvinyl chloride, and polyamides).
16. Production of ultramarine.
17. Production of chromium trioxide and chromates.
18. Production of artificial leather with the use of volatile organic solvents.
19. Production of esters.
20. Production of the products of organic synthesis (ethanol, ethyl ether, etc.) and petroleum gases at a rate of over 5000 $m^3$ per hour.
21. Production of intermediate products of the aniline dye industry in the benzene and ether series (aniline derivatives, nitrobenzene, alkyl amines, phenol, etc.) where total output is under 1000 tons per year.
22. Production of intermediate products in the naphthalene and anthracene series (1-naphthalenol, anthraquinone, phthalic anhydride, etc.) for a total output of up to 2000 tons per year.
23. Production of vat dyes from all types of azotols and azoamines.

24. Experimental plants in the aniline dye industry with a total capacity of 2000 tons per year and an output of under 1000 tons per year.
25. Plants for the production of asbestos goods.
26. Production of acetic acid.
27. Production of polyethylene and polypropylene from petroleum by-product gas.
28. Production of food and fodder yeasts and furfural by hydrolysis of wood pulp and agricultural wastes.
29. Production from petroleum by-product gases of ethylene and propylene copolymers and higher polyolefin polymers.
30. Production of tar, liquid and volatile distillates of wood pulp, methanol, acetic acid, turpentine, acetone, and creosote.
31. Production of nicotine.
32. Production of phenolic, polyester, epoxy, and other synthetic resins in amounts exceeding 300 tons per year.
33. Production of synthetic camphor by the isomerization process.
34. Production of melamine and cyanuric acid.
35. Production of polycarbonates.

*Class III: Health protection zone 300 m wide*

1. Production of bitumen and other products from the distillation residues of coal-tar, crude oil, pine tar (asphalt, polyasphalt, etc.).
2. Production of soda ash by the Solvay process in amounts under 400 000 tons per year.
3. Production of caustic soda by the Löwig and soda-lime processes.
4. Production of mineral salts, with the exception of the salts of arsenic, phosphorus, chromium, lead, and mercury.
5. Production of petroleum gas at a rate of 1000-5000 $m^3$ per hour and of producer gas at a rate of 5000-25 000 $m^3$ per hour.
6. Production of plastics.
7. Production of phenolic moulding materials and of moulded or rolled goods from paper and textiles impregnated with phenolic resins, in amounts exceeding 100 tons per year.
8. Production of artificial mineral dyes.
9. Rubber-reclaiming plants.
10. Production of tyres, industrial rubber goods, ebonite and bonded footwear, and the rubber stock used in their manufacture.
11. Chemical processing of rare metal ores for the extraction of salts of antimony, bismuth, lithium, etc.
12. Production of fertilizer mixtures.
13. Production of carbon goods for the electrical industry.
14. Vulcanization of rubber goods using carbon disulfide.
15. Production of acetaldehyde by the vapour-phase process without the use of metallic mercury.
16. Production and bulk storage of ammonia water.
17. Production of polystyrene and copolymers of styrene.
18. Production or organosilicon varnishes, liquids, and resins.

19. Plant for distributing gas to the mains network, including installations for odorizing the gas with mercaptans.
20. Production of sebacic acid.
21. Production of vinyl acetate, polyvinyl acetate, polyvinyl alcohol, polyvinyl emulsions, and acetals.
22. Production of polyfluorethylene resins.
23. Production of plasticizers.
24. Production of food and fodder yeasts by the hydrolysis of wood pulp and agricultural wastes (sunflower husks, maize stalks, straw, etc.).
25. Production of iso-octyl alcohol, butyric anhydride, butyric acid, foam plastic, vinyltoluene, polyvinyltoluene, polyurethane for casting, polyformaldehyde, reclaimed organic acids (acetic, butyric, etc.), formaldehyde, urotropin, penta-erythritol, methylpyrrolidone, polyvinylpyrrolidone, and of derivatives of petroleum gas, where production is less than 5000 $m^3$ per hour.
26. Production of lacquer, spirit varnishes, printer's varnish, varnishes for the rubber industry, insulating varnishes, etc.
27. Production of drying oils.
28. Production of phenolic, polyester, polyamide, epoxy, and other synthetic resins in amounts of up to 300 tons per year.
29. Production of metal carbonyls.
30. Production of methionine.
31. Production of antibiotics by biological methods.

*Class IV: Health protection zone 100 m wide*

1. Production of paper from prepared cellulose and rags.
2. Production of casein plastic and other protein plastics (amino plastics, etc.).
3. Production of glycerol.
4. Production of enamels from condensation resins.
5. Soap production.
6. Processing of animal organs.
7. Production of producer gas from coal and peat in amounts of up to 5000 $m^3$ per hour.
8. Chemical processing of rare metal ores to extract the salts of molybdenum, tungsten and cobalt.
9. Production of phenolic moulding materials and of moulded or rolled goods from paper or textiles impregnated with phenolic resins, where production does not exceed 100 tons per year.
10. Industrial hydrogenation of fats (using hydrogen produced electrolytically).
11. Salt making (evaporation and rolling).
12. Production of potassium salts for pharmaceutical purposes.
13. Production of rubberized footwear without the use of organic solvents and of rubber stock without the use of carbon black.
14. Production of liquid fertilizers.
15. Production of vanillin and saccharin.

16. Production of petroleum gas at a rate of up to 1000 $m^3$ per hour.
17. Production of moulding materials (phenol-formaldehyde, urea-formaldehyde, melamine-formaldehyde, organosilicon, etc.).
18. Production of artificial leather from polyvinyl and other resins without the use of organic solvents.
19. Production of polyvinyl plasticizers, vinyl plastics, plastic separators for polyurethane foam, aerated plastics, glass-fibre-reinforced plastics and expanded polystyrene.
20. Production of alkaloids and galenicals.
21. Production of natural mineral dyes (chalk, ochre, Prussian red, etc.).
22. Production of perfumes.
23. Production of tanning extracts.
24. Production of goods from synthetic resins, polymers, and plastics by various methods (moulding, extrusion, injection moulding, vacuum-forming, etc.).
25. Production of synthetic detergent powders.

*Class V: Health protection zone 50 m wide*

1. Production of inorganic reagents in plants without a chlorine shop.
2. Vulcanization of rubber without the use of carbon disulfide.
3. Production of carbon dioxide and "dry ice".
4. Production of artificial pearls.
5. Production of goods from plastics and synthetic resins (mechanical operations only).
6. Production of photochemicals (photographic plates, cine-film, and photographic paper).
7. Production of fertilizers using carbon dioxide.
8. Depots for cleaning, washing, and steaming-out tanks used for the transport of crude oil and petroleum products.
9. Production of various types of paper and cardboard from imported semi-processed materials; production of wood pulp and hemi-cellulose with the use of soda or monosulfite in plants where prepared monosulfite is used, spent lyes and other compounds are not burnt, and liquid sulfur dioxide is not used.
10. Production of printing inks.
11. Compounding of pharmaceutical preparations.
12. Production of condensed and liquified products from the separation of air.

### The metallurgical, machine-tool, and metal-working industries

*Class I: Health protection zone 1000 m wide*

1. Plant for secondary processing of non-ferrous metals (copper, lead, zinc) at a rate of over 3000 tons per year.
2. Coking.

3. Iron-smelting where the total volume of the blast furnaces is voer 1500 $m^3$.
4. Plants carrying out all processes of iron and steel production, with an output of over a million tons of iron and steel per year.
5. Steel-smelting by the open hearth and converter techniques in works equipped to process wastes (milling of Thomas slag, etc.), where output of the basic product exceeds one million tons per year.
6. Smelting of non-ferrous metals (including lead, tin, copper, and nickel) direct from ores and concentrates.
7. Production of aluminium by electrolysis of fused aluminium salts (alumina).
8. Smelting of special types of pig iron; production of ferroalloys.
9. Plants for the sintering of ferrous and non-ferrous metal ores and pyrites cinders.
10. Production of alumina.
11. Production of cast-iron sections in amounts exceeding 100 000 tons per year.

*Class II: Health protection zone 500 m wide*

1. Magnesium production by any technique except the chloride process.
2. Production of non-ferrous metals in amounts exceeding 2000 tons per year.
3. Plants for secondary processing of non-ferrous metals (copper, lead, zinc, etc.) in amounts from 2000 to 3000 tons per year.
4. Iron-smelting, where the total volume of the blast furnaces is between 500 and 1500 $m^3$.
5. Plants carrying out all processes of iron and steel production, with an output of up to one million tons per year of iron and steel.
6. Steel-smelting by the open hearth, converter, and electrosmelting techniques in works equipped to process wastes (milling of Thomas slag, etc.), where output of the basic product is less than one million tons per year.
7. Production of lead accumulators.
8. Milling of Thomas slag.
9. Production of antimony by pyrometallurgical methods.
10. Production of cast-iron sections in amounts from 20 000 to 100 000 tons per year.
11. Production of zinc, copper, nickel, and cobalt by electrolysis of their aqueous solutions.

*Class III: Health protection zone 300 m wide*

1. Concentration of metals without hot processing.
2. Production of lead-covered or rubber-insulated cable.
3. Production of cast-iron sections in amounts from 10 000 to 20 000 tons per year.
4. Plants for secondary processing of non-ferrous metals (copper, lead, zinc, etc.) in amounts up to 1000 tons per year.

5. Production of non-ferrous metals in amounts from 100 to 2000 tons per year.
6. Production of mercury and apparatus containing mercury (mercury rectifiers, thermometers, valves, etc.).
7. Iron-smelting, where the total volume of the blast furnaces is less than 500 m$^3$.
8. Casting of non-ferrous metal sections under pressure with an output of 10 000 tons of castings per year (9500 tons of aluminium pressure castings and 500 tons of zinc castings).
9. Production of metal electrodes with the use of manganese.

*Class IV: Health protection zone 100 m wide*

1. Manufacture of electrical engineering machines and apparatus (dynamos, condensers, transformers, projectors, etc.), where foundries and similar installations are small.
2. Production of bare cable.
3. Manufacture of boilers.
4. Production of metallic electrodes.
5. Metal-working factories for cast-iron, steel (in amounts up to 10 000 tons per year), and non-ferrous (in amounts up to 100 tons per year) castings.
6. Production of antimony by electrolysis.
7. Type foundries where lead may be emitted into the air.

*Class V: Health protection zone 50 m wide*

1. Metal-working industries using heat treatment, but with no foundries.
2. Production of alkali accumulators.
3. Type foundries.
4. Production of instruments for the electrical engineering industry (lamps, headlights, etc.) in factories without foundries and not using mercury.
5. Production of hard alloys and refractory metals in plants containing no departments for chemical ore processing.
6. Printing works.

## Mining of ore minerals and non-metallic minerals

*Class I: Health protection zone 1000 m wide*

1. Plant for the extraction of crude oil, where 0.5-1 ton of hydrogen sulfide is discharged per day and the oil has a high proportion of volatile hydrocarbons.
2. Mining of lead ores, mercury, arsenic, and manganese.
3. Plants for the extraction of natural gas.

*Class II: Health protection zone 500 m wide*

1. Plants for the extraction of phosphorite, apatite, or pyrites without chemical processing.

2. Plants for the extraction of fuel shales.
3. Mining of hard coal, brown coal, and other coals.
4. Open-cast mining of iron and complex metallic ores (with the exception of lead ores, mercury, arsenic, and manganese), and the quarrying of rock of grades VIII-XI.

*Class III: Health protection zone 300 m wide*

1. Plants for the extraction of crude oil, where the amount of hydrogen sulfide discharged is less than 0.5 tons per day and the volatile hydrocarbon content of the oil is low.
2. Quarrying of rock of grades VI-VII: dolomites, magnesites, asbestos, tars and asphalts.
3. Open-cast mining of metalloid compounds.
4. Production of briquettes from powdered peat and coal.
5. Hydraulic mines and wet-dressing plant.

*Class IV: Health protection zone 100 m wide*

1. Mining of rock salt.
2. Peat-cutting.
3. Mining of metal and metalloid ores in pits, except for lead ores, mercury, arsenic, and manganese.

## The building industry

*Class I: Health protection zone 1000 m wide*

1. Production of Portland, Portland-slag, and other cements in amounts exceeding 150 000 tons per year.
2. Kilning of magnesite, dolomite, and fire-clay in shaft or rotary kilns.

*Class II: Health protection zone 500 m wide*

1. Production of gypsum (alabaster).
2. Production of asbestos.
3. Production of lime in factories with shaft or rotary kilns.
4. Production of Portland, Portland-slag, and other cements in amounts up to 150 000 tons per year.
5. Production of asphalt concrete in mobile plants.

*Class III: Health protection zone 300 m wide*

1. Production of artificial fillers (clay and other fillers).
2. Production of glass wool and slag wool.
3. Production of local cements (calcined-clay cement, Roman cement, slag-gypsum cement, etc.) in amounts up to 5000 tons per year.
4. Production of tar paper and rubberoid roof-sheeting material.
5. Production of asphalt concrete in permanent plants.

*Class IV: Health protection zone 100 m wide*

1. Production of artificial stone and concrete articles.
2. Hoists for lifting cement and other dust-producing building materials.
3. Production of building materials from heat-and-power station wastes.
4. Production of articles from asbestos cement.
5. Production of polymerized building materials.
6. Production of porcelain ware and earthenware.
7. Production of red brick and silica brick.
8. Production of ceramic and refractory ware.
9. Production of stoneware.
10. Glass manufacture.

*Class V: Health protection zone 50 m wide*

1. Quarrying of rock without blasting and plants for working natural stone.
2. Production of plaster goods.
3. Production of reedboard, strawboard, etc.
4. Pottery production.

**The wood industry**

*Class I: Health protection zone 1000 m wide*

1. Chemical processing of wood and the production of charcoal.

*Class II: Health protection zone 500 m wide*

1. Production of charcoal by the retort process.

*Class III: Health protection zone 300 m wide*

1. Plants for impregnating wood in order to preserve it.
2. Production of articles from wood fibre using artificial resins as binders (chipboard, fibreboard).

*Class IV: Health protection zone 100 m wide*

1. Production of wood fibre.
2. Saw mills and factories producing plywood and wood parts for buildings of standard design.
3. Shipyards for the construction of wooden craft.
4. Production of wallpaper.
5. Production of vitamin-enriched pine-needle flour, chlorophyll-carotene pastes and pine extracts.

*Class V: Health protection zone 50 m wide*

1. Wood-working, manufacture of furniture, parquet, and boxes.
2. Plants for the protective treatment of wood by impregnation with aqueous solutions (other than arsenic salts).
3. Production of articles from wood fibre (chipboard, fibreboard, cement-fibrolite board, etc.).

4. Production of barrels using prepared staves.
5. Production of bast matting.
6. Boatyards for the construction of launches and small craft.

## The textile industry and light industry

*Class I: Health protection zone 1000 m wide*

1. Plants for the primary processing of cotton which have departments for treating seed with organomercury coumpounds.

*Class II: Health protection zone 500 m wide*

1. Plants for the chemical treatment and processing of textiles with carbon disulfide.
2. Production of artificial leather, sheeting, oilcloth, and plastic for shoe soles where volatile organic solvents are used at the rate of up to 2 tons per day.

*Class III: Health protection zone 300 m wide*

1. Plants for continuous impregnation of textiles and paper with oil-varnish, oil asphaltum, bakelites, and other varnishes, where the rate of production of impregnated material exceeds 300 tons per year.
2. Plants for the primary processing of vegetable fibres (flax, hemp, cotton, etc.).
3. Plants for the treatment and processing of textiles without the use of carbon disulfide (leatherette, leather substitute, etc.).
4. Bleaching, dyeing, and finishing plants.
5. Production of polyvinylchloride sheeting reinforced on one side, blended polymer sheeting, rubber for shoe soles, and reclaimed rubber, where solvents are used at the rate of one ton per day.

*Class IV: Health protection zone 100 m wide*

1. Plants for the continuous impregnation of textiles and paper with oil-varnish, oil-asphaltum, bakelite, and other varnishes, where the rate of production of impregnated material is less than 300 tons per year.
2. Manufacture of cottonin.
3. Silk filatures.
4. Manufacture of mixture fabrics.
5. Manufacture of hemp cordage, rope, and twine.
6. Manufacture of yarn and textiles from wool, cotton, and linen in mills with dyeing and bleaching departments.
7. Production of fancy leather board with polymer finishes, where organic solvents are used at a rate of up to 0.5 tons per day, and rubber for shoe soles without the use of volatile organic solvents.

*Class V: Health protection zone 50 m wide*

1. Manufacture of cotton, linen, and woollen yarns and textiles in mills without dying and bleaching departments.
2. Manufacture of knitwear and lace.
3. Silk weaving.
4. Clothing factories.
5. Manufacture of carpets and artificial astrakhan.
6. Production of insole board from leather and leather-cellulose fibre without the use of solvents.
7. Footwear manufacture.

### Processing of animal products

*Class I: Health protection zone 1000 m wide*

1. Factories manufacturing glue from hide remnants, bone refuse, and other animal wastes and residues.
2. Production of industrial gelatin from bone refuse, scrapings, hide remnants, and other animal wastes and residues in plants where such material is stored under cover or in the open air.
3. Salvaging plants for processing animal or fish wastes and residues into fats, animal feed, fertilizers, etc.

*Class II: Health protection zone 500 m wide*

1. Plants for roasting and grinding bones.
2. Fat rendering plants producing industrial fats and greases in amounts exceeding 30 tons per year.

*Class III: Health protection zone 300 m wide*

1. Plants for preparing belts for dyeing (sheepskin, tanned skeepskin, furs) and the production of suede, morocco leather, kid. etc., with facilities for processing wastes.
2. Plants for processing raw cattle hides; raw-hide dressing and tanning with facilities for processing wastes.
3. Production of industrial fats and greases in amounts up to 30 tons per year.
4. Wool-washing plants.
5. Storehouses for wet-salted and unprocessed hides (storage capacity for over 200 hides).

*Class IV: Health protection zone 100 m wide*

1. Production of skeletons and visual teaching aids from animal carcasses.
2. Feed concentrate plants using animal and food wastes.
3. Felt manufacture.
4. Production of high grade gelatin from fresh bones kept for as short a time as possible under refrigeration in special stores.

5. Plants for processing hair, bristle, down, feathers, horns, and hooves.
6. Production of gut and catgut.

*Class V: Health protection zone 50 m wide*

1. Manufacture of patent leather.
2. Manufacture of leather goods.
3. Manufacture of brushes from bristle and hair.
4. Depots for the temporary storage of wet-salted hides (up to 200), where no processing is carried out.
5. Felting shops.

### Food processing and the production of flavourings

*Class II: Health protection zone 500 m wide*

1. Stockyards to hold over 1000 head of livestock after shipment.
2. Abattoirs for cattle and sheep, meat-packing plants, and meat-packing houses, with stockyards for holding animals before slaughter that, at maximum capacity, represent three days' supply of meat.
3. Plants for melting down blubber from marine animals.
4. Plants for washing intestines.
5. Disinfection and cleansing stations for washing down trucks in which livestock have been shipped.

*Class III: Health protection zone 300 m wide*

1. Beet-sugar refineries.
2. Factories producing feed antibiotics.
3. Fisheries.
4. Stockyards holding up to 1000 head of livestock after shipment.
5. Plants for the production of enzymes by the surface culture technique.
6. Slaughterhouses for small animals and poultry.

*Class IV: Health protection zone 100 m wide*

1. Flour mills, hulling mills, grain shellers, and feed concentrate mills.
2. Grain elevators.
3. Coffee-roasting plants.
4. Cheese-making factories.
5. Production of oleomargarine and margarine.
6. Meat-curing plants.
7. Production of alcohol for the food industry.
8. Fish canneries and fish filleting plants with departments for processing wastes; fish-packing plants.
9. Plants for the production of enzymes by submerged fermentation.
10. Beet-sugar refineries without facilities for storing beet pulp.
11. Cornflour and corn syrup factories.
12. Production of albumin.
13. Vegetable processing (drying, salting, or pickling) plants.

14. Production of dextrin, glucose, and molasses.
15. Starch production.

*Class V: Health protection zone 50 m wide*

1. Confectionery factories.
2. Production of table vinegar.
3. Tobacco-curing plants and cigarette factories.
4. Tea-blending plants.
5. Distilleries.
6. Oil mills (vegetable oils).
7. Canneries.
8. Vegetable storehouses.
9. Sugar refineries.
10. Brandy distilleries.
11. Breweries (without malthouses).
12. Pasta factories.
13. Milk and dairy product factories.
14. Sausage factories with an output of over 3 tons per shift.
15. Factory-type bakeries.
16. Factories preparing foodstuffs.
17. Refrigerating plants with a capacity of over 600 tons.
18. Plants for the initial stages of wine-making.
19. Wine-making establishments.
20. Production of grape juice.
21. Production of fruit and vegetable juices and non-alcoholic beverages.
22. Plants for the production of commercial malt and yeast.
23. Fish-curing plants.

## Heat-and-power stations and boiler installations

Health protection zones for heat-and-power stations and boiler installations shall be determined in accordance with the dispersion in the air of the harmful substances contained in the wastes discharged, as calculated on the basis of the official publications on standards.

## Sanitary engineering installations and municipal undertakings

The width of health protection zones for sanitary engineering installations and municipal undertakings shall be established on the basis of the sanitary classification and production capacity of such installations and undertakings.

*Class I: Health protection zone 1000 m wide*

1. Controlled unimproved tips for liquid and solid domestic wastes of organic origin.
2. Fields where septic-tank contents are ploughed in or spread.

*Class II: Health protection zone 500 m wide*

1. Burial-places for cattle.
2. Salvaging plants for the disposal of animal carcasses and condemned meat.
3. Principal centres for salvage and incineration of refuse.
4. Improved tips for solid wastes.
5. Centralized composting areas for solid wastes and refuse from population centres.

*Class III: Health protection zone 300 m wide*

1. Cemeteries.
2. District centres for salvage and incineration of refuse.
3. Principal collection centres for utilizable wastes.
4. Cattle burial-places with carcass destruction chambers.
5. Outfall works.
6. Greenhouses and hothouses making use of refuse.
7. Composting of refuse containing neither manure nor fecal matter.

*Class IV: Health protection zone 100 m wide*

1. District collection centres for utilizable wastes.
2. Depots for vehicles used for refuse collection in towns.
3. Places for the temporary storage of scrap material without processing.
4. Servicing stations for heavy goods vehicles and for buses belonging to the urban transport system.

*Class V: Health protection zone 50 m wide*

1. Servicing stations for motor vehicles (cars, except for privately owned cars, and buses outside the urban transport network).

*Health protection zones for sewage treatment installations*

| Types of installation | Width of zone (in metres) for installations with treatment capacity of ($m^3$/day) < 200 | 200-5000 | 5000-50 000 | 50 000-280 000 |
|---|---|---|---|---|
| Installations for mechanical and biological treatment of sewage with sludge beds for digested sludge, and installations with sludge beds alone | 150 | 200 | 400 | 500 |
| Installations for mechanical and biological treatment of sewage and thermomechanical processing of sludge in closed premises | 100 | 150 | 300 | 400 |
| Filter beds | 200 | 300 | 500 | 1000 |
| Sewage farms | 150 | 200 | 400 | 1000 |
| Waste stabilization ponds | 200 | 200 | — | — |

*Notes*

Health protection zones for sewage treatment installations with a capacity exceeding 280 000 $m^3$/day and for installations not using approved sewage-treatment and sludge-processing techniques shall be established by joint decision of the Central Sanitary and Epidemiological Board of the Ministry of Health of the USSR and the State Committee for Construction of the USSR.

Filter beds with an area of up to 0.5 ha and installations for mechanical and biological treatment of sewage with a capacity of up to 50 $m^3$/day shall have a health protection zone 100 m wide.

Municipal sewage farms with an area of up to 1 ha shall have a health protection zone 50 m wide.

Underground filter beds with a capacity of 15 $m^3$/day shall have a health protection zone 15 m wide.

Where dwelling houses are located downwind of the treatment installations, the health protection zones may be enlarged, but to no more than twice the width indicated in the table. They may be reduced in the case of a favourable wind distribution.

The width of the health protection zones for sewage pumping stations shall be :

(*a*) 20 m for a treatment capacity of 50 000 $m^3$/day;

(*b*) 30 m for a treatment capacity exceeding 50 000 $m^3$/day.

Pumping stations with a capacity of up to 200 $m^3$/day are permitted a health protection zone 15 m wide.

The widths for health protection zones indicated in the table also apply to food production plants.

## Health protection zones for agricultural undertakings and agricultural premises

| Types of undertaking or premises | Width of health protection zone (metres) |
|---|---|
| Farms : | |
| stud farms and rabbit farms | 100 |
| cattle farms (all types), sheep farms, and fur farms | 300 |
| poultry farms | 300 |
| pig farms | 500 |
| Poultry factories | 1000 |
| Vetinerary surgeries | 200 |
| Hothouses and greenhouses : | |
| heated biologically (using manure) | 100 |
| heated biologically (using refuse) | 300 |
| using electrical, steam, or water heating systems | no standard |
| Premises for preparing feed : | |
| without the use of food wastes | no standard |
| with the use of food wastes | 100 |
| Undertakings and premises for the initial treatment and processing of milk, fruit, or vegetables | no standard |
| Garages and yards for the repair, servicing, and parking of cars and agricultural machinery, with a capacity of over 200 machine units | 100 |
| Storehouses for fruit, vegetables, potatoes, grain, other agricultural produce, and other stores | 50 |
| Buildings for housing animals and poultry kept for private use in residential areas | 50 |
| Storehouses : | |
| for mineral fertilizers | 200 |
| for mineral fertilizers and up to 20 tons of pesticides | 200 |
| for pesticides : | |
| up to 20 tons | 200 |
| 20-50 " | 300 |
| 50-100 " | 400 |
| 100-200 " | 500 |
| 300-500 " | 700 |
| over 500 " | 1000 |

### Warehouses

Health protection zones for warehouses shall be established in accordance with the existing design standards for the various types of warehouses as approved or accepted by the State Committee for Construction of the USSR.

*Annex 3*

## INFORMATION TO BE OBTAINED WHEN AN INDUSTRIAL UNDERTAKING IS INSPECTED

1. Name of undertaking.
2. Address.
3. Ministry responsible for the undertaking.
4. Nature of production.
5. Approximate production capacity.
6. Sanitary and topographical characteristics of the factory site, its size, and possibilities of extending it.
7. Sanitary characteristics of the factory, taking into account the prevailing winds in relation to residential districts (centres of population); size of the health-protection zone; does the factory comply with sanitary requirements? are its emissions polluting the air in residential districts?
8. List of workshops that give rise to air pollution, indicating the amount and composition of the gas and dust discharged into the atmosphere in tons per 24 hours (controlled and uncontrolled emissions); number and height of smoke-stacks and ventilation exhausts.
9. Does the undertaking have gas-purification, dust-separation and recuperation installations? if so, in what workshops, of what type, and of what degree of efficiency?
10. Other sources of air pollution (open stores of raw materials, coal, etc., areas covered with factory wastes, ash tips, spoil heaps, effluent outfalls, railway sidings, etc.); their role and relative importance in total atmospheric pollution by the undertaking concerned.
11. Characteristics of pollution of the air with industrial emissions: distance that pollution travels, degree of pollution of the atmosphere with individual ingredients as compared with maximum permissible concentrations.
12. Harmful effect of pollutants on sanitary and living conditions, on human health, domestic animals, green vegetation, etc.; does the local population complain? if so, of what?
13. Reasons for air pollution (obsolete engineering processes, low smoke-stacks, uncontrolled emissions, faulty sealing of apparatus and connexions, absence or inadequacy of gas-purifying plant, etc.; possibilities of eliminating these causes.

14. Prospects of developing the undertaking on the present site; existence of an approved reconstruction project; who drew up the project? address of the organization concerned; outline of sections of the project concerned with increasing the capacity of the workshops that pollute the atmosphere, and the measures envisaged for dealing with industrial emissions.
15. Conclusions of the health authorities regarding the possibility of leaving the undertaking on its present site, and prospects for its development, provided that health-improvement measures are taken (list and describe such measures), or regarding the removal of individual workshops or the undertaking as a whole to another site.

*Annex 4*

## QUESTIONNAIRE TO DETERMINE THE EFFECT OF ATMOSPHERIC POLLUTANTS ON LIVING CONDITIONS

In order to determine the effect of smoke, dust, and gases on sanitary and living conditions, the public should be questioned along the following lines:

1. Town .................. Street .................. No. ..................
2. Name .................. First name .................. Patronymic..................
3. Date of birth ..................
4. Occupation ..................
5. Length of residence in present dwelling ..................
6. Do gases, dust, and soot reach the house (yes, no)?
7. If so, from what factory? ..................
8. Distance from the factory or factories concerned ..................
9. An unpleasant, specific odour is perceived: strong, weak, constantly, from time to time, never *(underline where applicable)*.
10. Manifestations of illness: coughs, headaches, vertigo, nausea, grit in the eyes, none *(underline where applicable)*.
11. Do industrial gases and dust affect animals, trees, market gardens, garden flowers, domestic utensils *(underline where applicable)*? Is so, in what way?
12. Do the dust and gases interfere with ventilation of the flats (yes, no)?
13. Do dust or soot interfere with the drying of washing in the yard (yes, no)?
14. Has any difference been noted in the smokiness of the atmosphere during the last year (yes, no)? Has it increased, decreased, or ceased *(underline where applicable)*?
15. Date on which form was filled in ..................

Signature of the respondent ..................

The questionnaire should be answered by persons 18 years of age and upwards living at different distances (100 m, 500 m, 1 km, 2 km, and over) from a source of industrial pollution; the distance will depend on the absolute amount of the emission, the height of the smoke-stacks, and topographical conditions. At least 50–100 persons should be questioned in each zone.

## *Annex 5*

## STUDY OF EYE INJURIES

A special register should be kept of all cases of persons applying for out-patient assistance in removing foreign bodies that have entered the eye out of doors.

Attendance for such treatment should be registered in polyclinics in different *rayons* of the city having different dust burdens. It is recommended that cases be recorded roughly in the following form:

**Record form for cases of eye injury**

1. Town .................... 2. *Rayon* ....................
3. Polyclinic No. ....................
4. Surname, first name and patronymic ....................
5. Address ....................
6. Age .................... 7. Occupation ....................
8. Date of eye injury: Year .......... Month .......... Day .......... Time..........
9. Place where injury was sustained: *Rayon* .......... Street ..........
10. Nature of the foreign body: ash, coal particle, particle of sand, etc.[1] *(underline where applicable).*
11. Temporary unfitness for work: yes, no *(underline where applicable).* Complications: yes, no *(underline where applicable).* If so, what were they? *(diagnosis).*
12. Were further attendances necessary: yes, no *(underline where applicable).*

Signature of the registering clerk....................

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[1] To be determined visually with a magnifying glass.

## *Annex 6*

# SPECIMEN RECORD FORM FOR FULL MEDICAL EXAMINATION

1. *Oblast* ............ *Rayon* ............
   Town ............
   Settlement (centre of population) ............
2. Surname ............ 3. Age: ...... years ...... months (for babies)
   Sex: male/female
   First name ............ Patronymic ............
4. Education ............
5. Occupation and post (for working adults; in the case of children, separately for father and mother)
   Place of work ......... Name of undertaking ......... Type of production .........
   Collective farm ............ State farm ............
   Length of service: (*a*) altogether (from beginning of working life)
   (*b*) in present place of work
6. Length of residence ............
7. Main complaints in regard to health ............
8. Past illnesses ............
9. Development characteristics of children ............
10. Physical development: Height in cm ......... Weight in kg .........
    Chest circumference (in cm): when breathing normally ............
    fully expanded ............
    on expiration ............
    Spirometry: frequency of respiration per minute ............

*State of health according to medical examination* :

11. Skin, subcutaneous adipose tissue ............
12. Glands ............
13. Mucosae ............
14. Bones, joints and muscles ............
15. Nervous system ............
    Subjective complaints: headaches, insomnia, irritability, depression, lack of balance, vertigo, weak memory *(underline where applicable)*
    Knee reflexes ............ Muscle tone ............

Romberg sign .......... Dermographism ..........
Tendency to sweat ..........

16. Sensory organs: Sight .......... Hearing ..........
Smell .......... Taste ..........
17. Metabolism ..........
18. Endocrine system ..........
19. Respiratory organs: Nasopharynx ..........
Upper respiratory tract ..........
Bronchi ..........
Lungs ..........
20. Blood circulation: Heart ..........
Blood vessels ..........
Blood pressure ..........
Pulse .......... per minute. Rhythm ..........
21. Digestive organs:
Oral cavity ..........
Tongue ..........
Teeth (defects, caries, fluorosis) ..........
Stomach ..........
Liver ..........
Spleen ..........
Intestine ..........
22. Urinary system ..........
23. Genital system ..........
24. Results of radioscopy and radiography ..........
25. Diagnosis ..........
26. General conclusions regarding state of health ..........
27. Results of analyses:
Tests: Wassermann .......... Kahn .......... Wright ..........
Huddleson .......... Pirquet .......... Mantoux ..........
Blood: Haemoglobin .......... erythrocyte sedimentation rate ..........
Erythrocytes ..........
Leucocytes ..........
White blood picture ..........
*Plasmodium malariae* ..........
Urine: Specific gravity .......... Colour .......... Transparency ..........
Albumin .......... Sugar .......... White blood cells ..........
Casts .......... Cells from the urinary tract ..........
Sputum ..........
Date of first examination ..........
Doctors' signatures ..........

## *Annex 7*

# STUDY OF THE EFFECT OF AIR POLLUTION ON ANIMALS

The effect of air pollution on animals can be studied in two different ways:

1. *Veterinary examination of farm animals*

All animals (a whole herd) in a populated area exposed to air pollution and in a control area are examined by veterinary specialists. On the basis of the results obtained, conclusions are drawn regarding the state of health of the farm animals. If need be, the worst-affected animals are slaughtered and their organs and tissues sent for pathological and other examinations.

2. *Experimental study of the effect of air pollution on experimental animals (biological assay)*

It is recommended that biological assays be carried out in cases where advice and assistance can be obtained from a research establishment. The purpose of the assays is to study the reactions of experimental animals to exposure to harmful environmental factors (harmful gases and dust in the atmosphere, fodder grown in an area exposed to industrial pollution, etc.) under strictly controlled natural conditions, and subsequently to determine the degree to which specific pollutants accumulate in experimental animals.

The biological assays should be preceded by careful preparation, and in particular by a study of the literature, so that the investigators can, in full knowledge of the facts, select the most sensitive species of experimental animal, determine the duration of exposure, and choose methods for detecting the degree of accumulation of the test substances in the animal organs.

The species of test animal selected depends on its sensitivity to the substance being investigated. Preference should be given to animals whose sensitivity is close to that of man, and whose reactions to exposure to air pollutants are substantially comparable with those of the human organism.

It is recommended that young animals be selected for the assays, since the growing organism is known to be most sensitive to industrial toxins. The animals should be of identical age and sex, and of approximately equal weight.

Experience has been gained in carrying out this type of investigation in regard to the heavy metals, particularly lead. Rats and rabbits are recommended for such experiments. The unfavourable effect of lead on the experimental animals can be demonstrated by studying the accumulation of that metal in organs and tissues. Examination of the blood (for haemoglobin, basophilic erythrocytes and reticulocytes) and determination of the lead balance in the organism are also recommended.

A rough outline for setting up an experiment is given in the table.

BIOLOGICAL ASSAYS UNDER NATURAL CONDITIONS

| Group of experimental animals | Location of cages | Nature of food | Purpose of experiment |
|---|---|---|---|
| I | Residential district most polluted with industrial emissions (downwind from the sources of pollution) | Pure feeding-stuffs grown in a control area | Determination of the effect on the organism of individual pollutants following inhalation |
| II | Control area with clean air (in a direction in which smoke is not likely to be blown) | Pure feeding-stuffs grown in a control area | Control investigations |
| III | Control area with clean air (in a direction in which smoke is not likely to be blown) | Feeding-stuffs grown in an area exposed to industrial pollution | Determination of the effect on the organism of air pollutants ingested by mouth |
| IV | Residential district most polluted with industrial emissions (downwind from the sources of pollution) | Feeding-stuffs grown in an area exposed to industrial pollution | Determination of the effect on the organism of individual pollutants inhaled and ingested |

From this outline it will be seen that, depending on the purpose of the investigation and the technical facilities available, the assay can be limited to two groups of animals (I, II) or expanded to include two further groups (III, IV). The number of animals in each group should be at least 4–5 in the case of rabbits or 10–25 in the case of rats or mice.

The experiments can be extended by placing cages containing the animals at several points at different distances from the source of air pollution (e.g., 250 m, 500 m, 1000 m and more). The assay should be carried on for at least 3 months, and longer if weather allows. It is not recommended to carry out the experiments under low temperature conditions (+10°C and below), since this may lead to illness among animals susceptible to chills and winds.

The animal cages are placed at a height of 1.25–1.5 m above ground level in places not readily accessible to the general public. The animals should be under constant supervision; their general condition should be carefully observed and weight determinations and blood tests should be carried out regularly.

The animals should be looked after in accordance with the regulations concerning experimental animals. It is recommended that regular, or if possible, continuous aspiration tests be arranged so that the results of the experiments can be considered in the light of the concentrations of atmospheric pollutants present. Fodder given to the animals should be analysed for content of the pollutants being investigated (lead, mercury, fluorides, etc.).

Once the assay is completed, the animals should be sacrificed and their organs and tissues prepared for spectrum analysis. When small animals are used, the organs and tissues of several animals may be combined.

The fresh weights of the organs and tissues (bones, muscle, liver, kidneys, lungs, brain, etc.) are determined. The organs are then dried in a drying cupboard at a temperature of 95-100°C, after which they are weighed again.

The dried organs and tissues are placed in separate test tubes, labelled to show the date, the group of animals, and the organs concerned. They are then kept in the laboratory until spectrum analysis can be carried out.

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