HEALTH EFFECTS OF AIR POLLUTION

The realization that environmental contamination in general and air pollution in particular are not merely a nuisance to be tolerated as an inevitable accompaniment of urban life—even as a symbol of prosperity—has developed only over the last 20 years. While, originally, it was the obvious effects of air pollution on the environment—the soot, smoke, fumes, and smells—that aroused concern, it is now well established that such pollution is also directly harmful to health. The most striking demonstration of the threat to health constituted by air pollution has been provided by episodes such as the severe London fog of 1952, the effect of which was great enough to be shown by the increase in mortality. There is no doubt, however, that lower levels of pollution can also cause damage to health, though on a smaller scale.

Because of this situation, public health authorities, mainly but not exclusively in the developed countries of the world, have become increasingly conscious of the need to ensure that the air is as free as possible of noxious contaminants. The control of air pollution is also a field with which WHO has been much concerned. A symposium on the health effects of air pollution,1, 2 convened by WHO, was held in Prague on 6-10 November 1967 for the purpose of reviewing progress in the field in Europe since a previous symposium on the same subject held in Copenhagen in 1960. The Prague symposium, which was arranged in collaboration with the Czechoslovak Ministry of Health, also considered the lines along which future research might profitably be conducted and discussed what further progress might be made towards drawing up criteria, guides, and standards of air quality.

Sources and nature of air pollution in Europe

The background to the discussions was sketched in by Dr. P. J. Lawther (United Kingdom), who dealt briefly with the main sources and nature of air pollution in Europe. As in all highly urbanized and industrialized regions, air pollution in Europe is largely the consequence of the combustion of various types of fuel. Such fuel may be burned completely, as in the efficient equipment used in industry, or incompletely, as in less efficient domestic equipment. In general, the incomplete combustion of fuel gives rise to products which are more varied, complex, and objectionable than those produced by complete combustion. The difference is particularly marked in the case of coal, one of the two major types of fuel used, the grossly inefficient burning of coal in domestic grates being the most objectionable form of fuel usage since it produces large amounts of pollutants discharged at a comparatively low...
level. In the case of oil, however, the other major fuel, efficiency of combustion is less important than the size of the fuel-burning plant, since this determines the type of oil used. Thus, small domestic plants produce virtually no pollution. Large industrial plants, however, use oils containing higher proportions of sulfur compounds as impurities; these are converted, on combustion, into sulfur dioxide and sulfuric acid, so that such plants constitute a major source of these pollutants. Pollution caused by motor vehicle exhaust gases is merely a local problem in Europe, where the conditions necessary for the production of the famous Los Angeles photochemical smog (high car density, stagnant air, and strong sunlight) are unlikely to be found in combination.

The complete combustion of a carbon-containing fuel should give only carbon dioxide and water, and possibly also oxides of nitrogen from the fixation of the nitrogen of the atmosphere. Sulfur present as an impurity will yield sulfur dioxide and sulfuric acid. With incomplete combustion, the list of pollutants is extended to include carbon monoxide, finely divided carbon (smoke), complex organic compounds (including polycyclic aromatic hydrocarbons, some of which are carcinogenic), and also aerosols of tar droplets, if the fuel is rich in volatile matter. The exhaust gases from petrol engines contain carbon monoxide, hydrocarbons (whether in unburnt fuel or cracked), lead from anti-knock additives, and barium from lubricating oil additives.

Once discharged into the air, the "primary" pollutants from the combustion of coal may react with one another, particularly in fog, when concentrations may rise to comparatively high levels. Such reactions between pollutants may be complex in character and are not well understood; the most significant, from the health point of view, is probably the oxidation of sulfur dioxide to sulfuric acid.

Apart from combustion products, industry also produces many specific emissions, some of which appear only to be nuisances, such as red oxide fume from open-hearth steel works and cement dust. Others, such as beryllium, fluorides, and asbestos, constitute definite health hazards. Asbestos in particular has recently been the subject of considerable concern, because of its importance as a causal agent of mesothelioma.

In the case of particulate pollutants, the chemical nature of the pollutant may be of less importance than the particle size. Particles small enough to remain suspended in air indefinitely (say, less than 10 μ equivalent diameter) are capable of being inhaled and may then be retained for long periods in the lung; they are therefore of greater importance, from the point of view of health, than the larger particles of grit and dust.

**Routine monitoring for common pollutants**

The question of the routine monitoring of the air for common pollutants was discussed by Mr A. P. Avy (France). Such monitoring is particularly difficult in the case of the general pollution of the air of densely populated areas, since the number of sources of pollution and of pollutants may then be large. Under such conditions, it is first necessary to decide which substances are to be monitored. Historically, the main emphasis has been on the monitoring of combustion products, starting with smoke and dust and followed by sulfur compounds; more recently, vehicle exhaust gases have been added, together with carbon monoxide and hydrocarbons and, in particular, the carcinogenic hydrocarbon, 3,4 benzpyrene.

Of the pollutants mentioned above, dust is now considered to be of little medical importance, since dust particles are too large to be inhaled by man. From the medical point of view, the difficulty in deciding which of the various other pollutants should be monitored lies in the fact that no single substance has been identified as the cause of the morbidity and mortality associated with severe pollution. In particular, in the concentrations found in air none of the known pollutants would be expected to have any serious effects on health. In some way, therefore, it must be the polluted atmosphere
as a whole that is responsible for these effects, but it would be unrealistic to suppose that a network of stations could be established for the monitoring of all the factors involved. This could perhaps be effected by means of a small number of specially equipped stations; as far as routine monitoring is concerned, this should cover, as a minimum, sulfur dioxide, free sulfuric acid, nitrous gases, lead, and hydrocarbons. Such routine monitoring should be carried out by a number of stations scattered throughout the area concerned. In addition, in order to provide a basis for comparison, "background" or "zero" stations are required, located away from centres of population and industry.

The National Survey of Air Pollution in the United Kingdom may perhaps provide a model for similar surveys in other countries. In this survey, monitoring stations were located in a number of towns chosen as representative of the range of pollution levels expected under the different conditions existing in urban areas. These stations were located in districts of high-density old-fashioned housing, districts of low-density modern housing, smoke-control areas, industrial areas, mixed industrial and residential areas, and shopping and commercial centres. The measurements made by the various stations provide a basis for comparison with those made in other towns, and also for assessing the extent of any changes in pollution levels resulting from changes in the types of fuel consumed or from pollution control activities.

**Experimental investigations**

Other valuable background information is obtained by the analysis of certain gaseous effluents. Thus the exhaust gases from diesel engines, often considered to be a major source of pollution, have been shown repeatedly not to contain sufficient amounts of any toxic substance to produce harmful effects on the human body; they contain little or no carbon monoxide, and are unimportant as a source of benzpyrene and other polycyclic hydrocarbons. Similarly, the amounts of polycyclic hydrocarbons discharged by petrol engines in London are low in comparison with those produced by the burning of coal.

Experimental investigations have also been carried out with individual pollutants, on both man and animals. Sulfur oxides, in particular, have been the subject of a large amount of experimental work, although it is probable that the concentrations of these substances should be regarded mainly as an index of the general level of pollution. Urban atmospheres normally contain about 0.2 ppm of sulfur dioxide, while the maximum 48-hour value in the London fog of 1952 was 1.34 ppm, and spot samples taken by the Air Pollution Research Unit of the Medical Research Council revealed maximum concentrations of up to 2.0 ppm. These concentrations are insufficient to produce the harmful effects on man caused by air pollution.

Laboratory experiments have only exceptionally shown any increase in airway resistance due to individual pollutants or mixtures of pollutants. Sulfur dioxide, in particular, is so soluble as to be able only rarely to penetrate the respiratory tract beyond the bifurcation of the trachea. Techniques have therefore been devised whereby sulfur dioxide (and sulfuric acid) are adsorbed, before being administered, on porous particles of carbon which are capable of penetrating more deeply into the respiratory tract. Experiments in which this technique was used failed to show any, even transient, effects on airway resistance for concentrations of sulfur dioxide up to 2 ppm. In certain sensitive subjects, however, airway resistance is increased with a sulfur dioxide concentration of 5 ppm.

In what is known as the London Bridge experiment, a long-term study has been carried out on the effects of London atmospheres on airway resistance. The essence of this experiment is that, each working day since October 1964, a member of the staff of the Air Pollution Research Unit of the Medical Research Council, after travelling to London by train and walking the two miles from the station across London Bridge to the research laboratory, has immediately gone into the plethysmograph chamber.
resulting measurements of airway resistance have been plotted against the corresponding concentrations of smoke and sulfur dioxide, and highly significant positive correlations have been found for both pollutants during the winter months. Since the person concerned had been shown to be resistant to sulfur dioxide, the increase in airway resistance cannot be due to this substance alone. Some unknown substance is therefore responsible for the correlation between airway resistance and air pollution during the winter, and it is now believed that it may be a pharmacologically active substance such as a histamine potentiator. Experiments are now being conducted with aerosols of water-soluble extracts of smoke, and one such extract has been found capable of potentiating the action of histamine in guinea-pig gut.

Other experimental work of interest on a particular pollutant is that carried out by Professor H. W. Schlipkötter in the Federal Republic of Germany on benzpyrene. Since the possible effects of this substance depend on the amounts deposited in the respiratory tract, its rate of clearance by the body was investigated. For this purpose, soot impregnated with benzpyrene was administered to animals, and it was found that up to 80% was eliminated within three days. The body therefore appears to be able to deal with this substance very rapidly.

Methodology of epidemiological studies

The statistical aspects of epidemiological studies must not be forgotten; in particular, the data obtained must be adequate for statistical analysis to be applied. All important variables should be included, and this may mean that socio-economic, occupational, housing, and other factors should be taken into account, though few attempts have so far been made to do so. As a result, the problem may become extremely complex in character, but modern techniques, including the use of computers, now enable vast amounts of information to be assimilated and processed. Computers can also be used in simulation studies in which certain factors or parameters can be changed arbitrarily so as to obtain a series of hypothetical models, which can then be compared with observations.

Epidemiological studies of the effects of air pollution are complicated by the close association known to exist between cigarette smoking and disease, and this must be taken into account in all investigations in which comparisons are made between different populations. A further complication is introduced by the fact that the effects of air pollution develop over a long period, during which time changes in economic and social patterns may also have occurred.

Statistical data on mortality and morbidity might be thought to provide a reliable source of information for epidemiological studies. In fact, such data contain major sources of error and must be used with care if any attempt is to be made to compare the data for different countries or regions. As far as mortality data are concerned, the more important sources of error include:

(a) differences in diagnostic facilities and standards, and in the proportion of cases diagnosed after autopsy;

(b) differences in medical traditions in different countries, e.g., a disease described as bronchitis in one country may be described as emphysema in another, while the association between cardiac and respiratory diseases is often such that a case may be diagnosed as bronchitis in one country and congestive heart failure in another;

(c) advances in medical knowledge may reduce fatality rates for certain diseases or influence the number of cases attributable to certain causes, while the definition of new diseases results in a decrease in the number of cases assigned to older established disease groupings;

(d) differences in standards of death certification.

Mortality data give satisfactory results only if the population involved is of adequate size for the overall picture not to be obscured by random fluctuations. A more sensitive index is provided by special groups of the population, such as males over 45 years of age, but, as before, the total daily numbers must be
large enough not to be affected by random fluctuations; this index is suitable, therefore, for the study of large populations only.

Morbidity rates should also provide a more sensitive index, but are difficult to obtain and use, since the borderline between health and disease is usually somewhat indefinite; the concept of "illness" may be differently defined in different countries, or in different social classes in the same country. According to Dr A. E. Martin (United Kingdom), the requirements to be satisfied by a good morbidity index may be summarized in the following terms:

(a) the criteria for determining sickness must be sufficiently constant to yield comparable daily results without gaps at weekends (national insurance statistics are therefore unsatisfactory), and cyclical variations must be sufficiently consistent to enable the necessary statistical corrections to be made;

(b) the figures must be sufficiently numerous for interference by random fluctuations to be avoided;

(c) the population group selected must be a susceptible one, such as patients suffering from chronic bronchitis.

Examples of the use of mortality and morbidity data in epidemiological investigations are described later.

For many purposes, questionnaires provide the only valid method of making comparative studies, since they are based on symptoms and are therefore not affected by differences in diagnostic habits or traditions. An example of a questionnaire which has been successfully used in a number of countries is that developed by the Committee on the Aetiology of Chronic Bronchitis of the Medical Research Council of Great Britain. As pointed out by Dr T. Mork (Norway), a standardized questionnaire does not, in itself, automatically guarantee complete comparability; it is also necessary to standardize the interviewing technique. This has been achieved, in the United Kingdom, by making recordings of typical interviews in which certain difficulties arise and demonstrating the methods to be used to elicit unequivocal answers, and of interpreting the answers obtained. Linguistic problems arise, however, in translating questionnaires from one language to another and in the study of recordings of the type mentioned above by investigators speaking a language different from that in which the recordings were made. All translations should be made in close cooperation with physicians familiar with the phrases used to describe medical symptoms by the populations to whom the questionnaire is to be submitted.

The symposium considered that greater attention should be paid to the preparation of questionnaires suitable for the investigation of respiratory and other diseases among children. In the study of the effects of air pollution, questionnaires make it possible to obtain data on such subjects as social class, socio-economic factors, smoking habits, and occupation.

Immediate effects of air pollution

Epidemiological studies of the immediate effects of air pollution in the United Kingdom have made use of both mortality and morbidity data. Thus, as pointed out by Dr Martin, sudden increases in air pollution in London and other cities of the United Kingdom have often been associated with immediate increases in the mortality and morbidity. The effects are closely associated with meteorological conditions which prevent the dispersion of smoke and fumes and, in particular, those from domestic fires. They occur within a few hours of the development of high levels of pollution, cease shortly after the levels have fallen once again, and have been seen, in their most dramatic form, in London, in the various severe fogs which have occurred there in the period 1952-62. Even small increases in air pollution have been shown, however, to be accompanied by small, but definite, increases in mortality and morbidity. Longitudinal studies of this type do not require the use of a control population, and many of the difficulties otherwise experienced in the investigation of the chronic effects of air pollution do not arise.

Mortality data from all causes and from
bronchitis and cardiovascular diseases provided the basis for the conclusions described above and gave satisfactory results, thanks to the size of the population involved (Greater London has a population of nearly 10 million); with smaller populations, the picture will be obscured by random fluctuations.

The daily numbers of applications for admissions to hospitals through the Emergency Bed Service have provided a valuable index of morbidity in London. Another, which has also yielded good results and is suitable for relatively small populations, is based on the daily numbers of new cases of acute respiratory illness seen by general practitioners.

An example of a prospective study in which indices of mortality and morbidity have been used is that begun by the Ministry of Health in London during the winter of 1958-59. The aim here was to identify and measure the effects of improvements in the London atmosphere; in addition, since the smoke content has been steadily falling while the sulfur dioxide content has remained practically unchanged, it was hoped to obtain some indication of the relative importance of these two pollutants from the medical point of view. It is of interest, therefore, that when a serious fog occurred in 1962, the immediate effects on man were far less serious than those produced by the very similar fog of 1952, the number of deaths being only some 700, as compared with 4000 in the earlier episode. It would thus appear, at first sight, that the reduction in smoke content had resulted in a marked decrease in toxicity. Other factors may have come into play, however, such as possible differences in the susceptibility of the population. Furthermore, the warnings given on radio and television at the beginning of the fog may have induced susceptible members of the population to remain indoors.

A further reduction in smoke pollution in London has taken place since 1962, but a comparison of the mortality and morbidity associated with specific levels of pollutants with the corresponding figures for 1958-62 does not show any detectable improvement. Since sulfur dioxide is not the responsible agent, these results suggest that the effects of acute pollution are complex and that it is not sufficient merely to measure the smoke and sulfur dioxide.

Another factor to be taken into account is the effect of the Clean Air Act of 1956 (which prohibits the emission of dark smoke and requires plant of certain types to be fitted with apparatus for arresting grit and dust) in diminishing the amount of smoke and solid matter in the atmosphere. The opacity of London fogs is therefore decreasing, and consequently such fogs will be more easily dispersed by solar radiation. Moreover, with the increased use of central heating in blocks of flats and office blocks, the heat emitted in the centre of London has probably increased considerably in recent years, and this will tend to increase atmospheric turbulence. It is thus possible that the reduction in the incidence of polluted fogs in London observed during the last five or six years is due to changes in the nature of the fuel burned.

The use of diaries kept by people belonging to a susceptible group of the population, as a method of obtaining suitable morbidity data, was first applied in 1954 in London. Each winter, groups of up to 1000 patients suffering from chronic bronchitis or emphysema are given such diaries and asked to record, each day, by means of a simple code letter, whether they are feeling better than, the same as, or worse than, the day before. Statistical analysis of the results has shown a close association with air pollution during the winter months; quite small changes in pollution are immediately reflected.

Delayed effects of air pollution

Bronchitis

As far as the delayed effects of air pollution are concerned, numerous comparative studies carried out in different parts of the world have shown the existence of an urban factor in the etiology of bronchitis. The position is complicated, however, because of the established association between this disease and cigarette smoking. In addition, laboratory, experimental, clinical, and epidemiological studies have so far failed to show that any single
pollutant or combination of pollutants is the causal agent of the disease, so that more complex mechanisms may be involved. It is therefore necessary to examine the whole question of respiratory irritants.

This was considered by Professor N. G. M. Orie (Netherlands), who pointed out the need to take into account not only the type and amount of irritant present in the respiratory tract but also factors such as the degree of sensitivity of the subject, the state of the respiratory tract, the site of action of the irritant, and the specific tissue affected. The importance of the last-named factor is shown by the fact that the administration of doses of sulfur dioxide large enough to produce bronchial obstruction virtually fails to produce any reaction in the nose. This result suggests either that the bronchial and nasal mucosae are different in nature, or that sulfur dioxide acts specifically on the bronchial musculature.

A further difficulty is that, while good experimental and laboratory methods are available for assessing the acute effects of irritants, this is not true in the case of chronic effects, where epidemiological methods have to be used. In addition, the effects of the small amounts of pollutants present in air are difficult to determine and the results obtained often conflicting.

The sensitivity of the bronchial tract is also affected by a number of factors. It was thought at one time that most cases of obstructive lung disease were due to a combination of reactions to allergic stimuli and to non-specific irritants. It is now known that mediators may also be present, but little is known of the part they play in man. Another factor that may influence sensitivity is lung function, since a correlation has been found between sensitivity and the one-second forced respiratory volume test. The tissue affected is also of importance since, particularly in the young, it is often the nose which is most sensitive, while the bronchi react more slowly and at high irritant concentrations. Among older people, the situation is usually the reverse, and it is the bronchi which are more sensitive. Heredity is also known to play an important part in determining sensitivity.

According to Professor Orie, there is now a much greater need than in the past for quantitative assessment of the effects of irritants (both in terms of different parameters and in different patients) and greater knowledge of the action of any possible mediators and of the protection afforded by as many selectively acting drugs as possible. In public health and practical medicine, much illness can probably be prevented by the elimination of as many sources of irritation as possible in the patients' surroundings, protecting patients with the appropriate drugs and selecting, for high-risk occupations, people who have been shown to have a high threshold to bronchial irritation.

**Lung cancer**

Lung cancer is a further possible delayed effect of air pollution. There is considerable doubt, however, whether any relationship between air pollution and this disease really exists. The arguments in favour of the existence of such a relationship are based partly on the fact that the mortality from lung cancer, when urban and rural populations are compared, is greater in the former, and partly on the fact that carcinogenic polycyclic hydrocarbons, and in particular 3,4 benzpyrene, are known to be present as pollutants in the atmosphere. There can be no direct cause and effect relationship between lung cancer and the polycyclic hydrocarbons present in the atmosphere, however, as may be shown by the following considerations. The highest concentrations of polycyclic hydrocarbons must have been present in the atmosphere of the cities of the United Kingdom around the turn of the century, when city centres were densely populated and large amounts of coal were used, which were burnt less efficiently than in more recent years. Since that time, there has been a steady decrease in the polycyclic hydrocarbon content of the air. Even if it is assumed that a period of 20 years or more is required for the development of lung cancer, it is clear that this decrease in polycyclic hydrocarbon content has occurred at the same time as an increase in the incidence of lung cancer.

Other evidence making it seem unlikely that
any relationship exists between air pollution and lung cancer is the fact that the mortality from this disease is high in countries such as Finland, where air pollution levels are low. In the Channel Islands, where cigarette consumption is the highest in the world, air pollution is negligible, but the lung cancer rate is very high. In the USA, a study of the Seventh Day Adventists, a religious sect whose members do not smoke, showed that lung cancer rates among them were the same, whether they lived in polluted or non-polluted areas.

Dr. J. Clemmesen described the results obtained in a series of investigations carried out in Denmark, which illustrate some of the difficulties that may be encountered in epidemiological studies of lung cancer. The first stage in these investigations was to determine whether the increase reported in lung cancer since the beginning of the century was real. The extent of the increase was, in fact, difficult to determine with certainty, partly because, in the early years of the century, data were not given separately for the two sexes. In addition, the same disease might be diagnosed differently in men as compared with women, since men had a higher chance of being admitted to hospital; cases of lung cancer among women were therefore more likely to be diagnosed as bronchopneumonia.

In order to determine whether the increase in lung cancer was due to more accurate diagnosis and therefore only apparent, the radiograms taken during the course of examinations for the detection of pulmonary tuberculosis were re-examined. This re-examination was restricted to persons over 40 years of age, so as to avoid excessive weighting in favour of the younger age groups. On this basis a true increase in lung cancer was found. In addition, during the period of greatest increase, diagnostic efficiency and the percentages of hospital admissions, histological confirmations, and autopsies all remained the same.

Further confirmation of the reality of the increase was provided by the fact that, even if all deaths ascribed to pneumonia or bronchopneumonia among females in the 45-64 age group during the period covered by the investigation had been due to lung cancer, the annual total of such deaths was less than the deaths due to lung cancer among a similar group in 1953.

In Denmark, as elsewhere, the observation that lung cancer rates in urban areas are higher than those for rural areas was used as evidence in favour of the hypothesis that air pollution, and not cigarette smoking, is the main causative factor. It was found, however, that if allowance was made for a time-lag of five years for provincial towns and about 15 years for rural areas, as compared with Copenhagen, the age curves coincided very closely. This suggested that the same etiological factors existed in both town and country, and that the differences could be explained simply by the time-lag with which these factors came into operation in provincial towns and rural areas.

A similar time-lag was found in an examination of cohort patterns in town and country. This showed that the levels of the age curves were higher the later the cohort was born. Increases in levels were not uniform, however, and the increase for Copenhagen was particularly great as between cohorts born around 1875 and 1885, while a similar increase was found for provincial towns five to ten years later, and later still for rural areas. Finally, the increase in lung cancer took the form of a peak in the age-distribution curve which, with the passage of time, moved with the cohort to the older age groups. This suggested the existence of a factor affecting persons born at the same time. Air pollution, however, would not affect a particular age group in this way, but would be expected to cause a displacement of the age curve as a whole to a higher level. No such tendency was observed.

In conclusion, therefore, although 3,4 benzpyrene and other polycyclic hydrocarbons are undoubtedly carcinogenic, there is no evidence that, in the amounts normally present in air, they have any detectable effect in causing lung cancer. It is not possible to exclude air pollution completely as a causal agent of the disease, but its effects, if any, are negligible in comparison with those of cigarette smoking.
The case of carbon monoxide

Pollution of the air by carbon monoxide calls for special consideration. Apart from cigarette smoking, the only major source of this pollutant in urban areas is to be found in the exhaust gases from motor vehicles. For this reason, numerous surveys have been made of the carbon monoxide concentrations present in the air of urban areas, while measurements have been made, more recently, of the amounts present in the blood of drivers of motor vehicles and other persons exposed to exhaust gases over long periods, such as traffic police.

The distribution of carbon monoxide in the atmosphere of urban areas was reviewed in a paper by Mr P. Chovin and Mr L. Truffert (France). The concentrations found depend on a number of factors, such as:

(a) the site of the monitoring instrument and the values found depending on whether the instrument is located at the centre or side of the road, near a point where cars are frequently stopping and starting, etc.;

(b) the height of the instrument above the ground (the exhaust gases are usually emitted less than one metre from the ground);

(c) the wind velocity (the distribution is markedly affected by winds of velocity greater than 2 m/sec at roof level in a road lined by houses);

(d) the rate at which vehicles pass the measuring instrument; quickly moving vehicles set up air currents which increase the rate of dispersion of the carbon monoxide, while with stationary vehicles not only are these currents absent but the amounts of carbon monoxide produced are greater, owing to the richer mixtures used under these conditions and the fact that carburettors are often badly adjusted.

In Paris, the area of the city has been divided into 317 squares, in each of which a sampling site has been located at a point of maximum risk for pedestrians, other persons particularly exposed to the action of exhaust gases, such as the police, and people living on the ground floors of the houses lining the roads concerned. Four instantaneous samples are taken every month at each site, giving a total of just over 15,000 samples per year. On the basis of the results obtained, maps can be drawn up showing the distribution of carbon monoxide over the area of the city.

In addition to the monitoring of carbon monoxide concentrations mentioned above tests have also been carried out in Paris on the carboxyhaemoglobin content of the blood of 331 traffic policemen, each of whom remained on duty for five hours at the centre of a road crossing where pollution was very high. In the case of non-smokers, it was found that the content was about half that corresponding to equilibrium between the blood and the carbon monoxide in the air. Tests have also been carried out, by means of a method devised by the Air Pollution Research Unit of the Medical Research Council of Great Britain, for which a blood sample of only 0.1 ml is required, on London policemen on traffic control duty, car drivers in London, and customs officers and other people on car ferries exposed to high carbon monoxide concentrations. For non-smokers, the tests showed carboxyhaemoglobin values generally less than 2% saturation, while for smokers, the figures were mostly in the range 4%-6%.

There is thus a very wide margin between the carboxyhaemoglobin content found in the blood of persons exposed to vehicle exhaust gases, and the 66% saturation which usually proves fatal. This last figure, in fact, would correspond to an atmospheric concentration of 1500-2000 ppm, while street concentrations rarely exceed 30 ppm, though peaks of up to 360 ppm may occur. The problem is, therefore, whether such small concentrations of carbon monoxide can have any appreciable physiological effects. Many such effects have been described, including disturbances in visual acuity, decreases in the retinal fields of vision and of retinal sensitivity for red and green, changes in reflex activity, forgetting of learned behaviour, and diminution in the ability to make fine measurements. Much of the earlier work in this field is now considered to be unsatisfactory, since it was carried out under insufficiently rigorous conditions. A series of carefully controlled experiments is now being carried out at the
Air Pollution Research Unit of the Medical Research Council. Preliminary results have shown no diminution in the ability to distinguish between fluttering sounds or flickering lights, for a blood content of carboxyhaemoglobin of 10% saturation.

Other body tissues, apart from blood, might also be affected by carbon monoxide. Thus the inhaling of a puff of cigarette smoke results in the bronchial epithelium coming into contact with a concentration of about 2% of carbon monoxide, which would be lethal if inhaled continuously from the atmosphere for a short period. In addition, therefore, to the study of the physiological effects of low concentrations of carbon monoxide in the blood, a search should be made for effects on other tissues.

Criteria, guides, and standards of air quality

The final question considered by the symposium was that of criteria, guides, and standards of air quality. As a basis for discussion, the principles and definitions agreed at the WHO inter-regional symposium on criteria for air quality and methods of measurement in 1963 and endorsed by the WHO Expert Committee on Atmospheric Pollutants were accepted.

The symposium suggested that a further definition, namely that of "standards" or "norms", should be added to those given by the Committee, as follows:

Standards or norms of air quality are guides which have been adopted by a country and made compulsory. The various countries will define their standards in the light of an appreciation of their own problems.

In this field, as pointed out by Professor M. S. Gol’dberg, the USSR has pioneered the introduction of legislation laying down the maximum permissible concentrations of harmful substances in the atmosphere of urban areas. The experimental work on which this legislation has been based was in progress as early as 1949, under the direction of Professor V. A. Rjazanov; its aim was to detect very small changes in the organism characteristic of the defence and adaptation reactions caused by microconcentrations of toxic substances in the air, and to discover the biologically harmless level. This level was then taken as the maximum permissible concentration. Up to the present, such maximum permissible concentrations have been adopted for 95 individual substances and 17 mixtures of substances that may be present in the atmosphere.

Both instantaneous and average daily maximum permissible concentrations are laid down. For the former, the values laid down are lower than both the odour threshold and that of any subsensory reflex reactions, and especially those capable of causing changes in the functional state of the cerebral cortex. For the latter, the values adopted are such that no functional changes occur indicative either of a divergence from the physiological optimum or of the mobilization of a defence mechanism.

It is recognized in the USSR that it is not always possible immediately to ensure that concentrations of pollutants are less than the prescribed maximum permissible values. Slightly higher concentrations are then permitted for a limited period. A distinction is made, in fact, in the USSR, between "hygiene standards", which are based on purely scientific, medical, or physiological criteria, and "sanitary standards", which take into account practical difficulties in achieving the hygiene standard in any given area.

In the USA, legislative action in the field of air quality standards has been taken at both state and federal levels. Thus, the California State Department of Health adopted standards in 1959 defining three different levels of pollution, as follows:

(1) adverse level, the level at which there will be sensory irritation, damage to vegetation, reduction in visibility, or similar effects;

(2) serious level, the level at which there will be alteration of body function or which is likely to lead to chronic disease;

(3) emergency level, the level at which it is likely that acute sickness or death in sensitive groups of the community will occur.

Standards were also laid down for the hydrocarbons and carbon monoxide present in vehicle exhaust gases. At the federal level,
the Air Quality Act of 1967 provides for the development of air quality criteria and the adoption of air quality standards by the individual states; in addition to California, a number of States have already adopted such standards.

In view of the action already taken in certain countries to establish criteria, guides, and standards and of the opinion expressed by the WHO Expert Committee on Atmospheric Pollutants that international guides to air quality are desirable and should be established in the near future, the symposium considered whether it should recommend that such guides should now be established for the European Region. While there was general agreement on the principles to be followed in drawing up guides, difficulties are encountered in practice, as is shown by a comparison of the maximum permissible concentrations adopted in different countries. The symposium considered that it would be unfortunate if guides not based on completely reliable evidence were published. The next step, therefore, should be an assessment of the available evidence, further research, where needed, and the checking of work of doubtful validity. A working group should be established for this purpose.

If international guides to air quality are issued, they will be used in a wide variety of countries, in which the social conditions, administrative and legal systems, and stages of development differ markedly. Under these circumstances, the less developed countries should not aim at too high a standard, since the resources required may not be available or could be made available only by neglecting other important aspects of public health, such as the provision of supplies of pure water. From the point of view of the developed countries, however, high standards are necessary so as to provide an incentive for further improvements in air pollution control. Developing countries should therefore be advised to draw up a system of priorities for the various aspects of public health, in which air pollution should be given its proper place. Such countries should always give careful consideration to the location of factories, since an incorrectly located factory, once established, may pollute the atmosphere of the surrounding area for many years.

Some participants put forward the point of view that too much emphasis was being placed on the subject of guides and standards and on the need for countries to adopt standards. A more pragmatic approach to the problem of air pollution has been followed in the United Kingdom, where, for the processes registered under the Alkali Act, the best practicable means must be used for preventing emissions but statutory maximum limits, except in a small number of cases, are not laid down. As far as other pollutants are concerned, the Alkali Inspectorate, which administers the Act, imposes limits which it considers to be in conformity with the current best practicable means and which often take local conditions into account. Emissions of domestic smoke may be controlled under the Clean Air Act, by the establishment of smoke control areas by local authorities; the role of the Government is confined to exerting pressure on these authorities to take the necessary action. The policy adopted in the United Kingdom, therefore, is one of taking energetic practical action to reduce pollution, and this is considered as of greater importance under present conditions than attempting to define the precise composition of what might ultimately be accepted as pure air. The amounts of specific substances such as carbon monoxide, lead, fluorides, and asbestos present in the air should be under constant review and should be considered in the light of the most recent advances in medical science rather than by reference to a standard.

The symposium concluded that, although the publication of international guides to air quality would be useful in enabling countries to assess the air pollution problems with which they are confronted, practical steps to control air pollution should not await such publication or the adoption of national standards of air quality. The nature of the steps to be taken is usually obvious, and there should be no delay in drawing up air pollution control programmes.

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