GENERAL PRINCIPLES FOR THE ABATEMENT AND CONTROL OF AIR POLLUTION

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INTRODUCTION

The demand for clean, pure air comes ultimately from the general public. It may come from a villager who realizes that the fumes from a nearby factory make his village much less pleasant to live in than other villages in the district, or from the inhabitants of a wider area who are worried that a planned industrial development project may cause unpleasant or harmful pollution in the places where they live. It may be that the inhabitants of a town have found that air pollution is worse in their town than in others in the same country, or even, on a national scale, that townspeople in one country have become aware that the air pollution they have to tolerate is worse than that in many other countries. In addition, concern is expressed by those who are, perhaps, a little frightened by the scale of modern technology and the possibility that the resulting emissions of pollutants into the atmosphere may lead to undesirable changes in the existing balance of nature between competing species of living organisms or even to catastrophic changes in the climate of the earth.

These pressures may be either towards new legislation or the more vigorous application of existing legislation. The arguments will probably be grossly oversimplified, taking into account only one facet of a complex of problems stretching far beyond the narrow field of air pollution. The demands for action will be directed to the country's political leaders, as the ultimate source of power.

At this stage, the first questions to be answered concern the validity of the complaints and seriousness of the situation complained of, so that the demand for action may be properly placed in the waiting list for funds to allow remedial action to be taken. The answers to the questions will depend on technical and medical advice, but the ultimate decision is a political one, depending, among other

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things, on the readiness of the general public or industry to agree to the necessary remedial measures that may be required.

The next problem, or set of problems, is concerned with the technical options available for achieving a solution, considered in connexion with the possible economic consequences. Then come questions about the legislative and administrative options for putting the favoured technical solution into effect. Again, the final decision rests with the politicians. Lastly, arrangements have to be made to assess the improvement effected by the legislative or administrative changes adopted. Since improvements can be obtained only at a certain cost to the economy, at least in the short term, the value obtained in relation to the cost must always be kept under review.

In this chapter the various options that present themselves throughout the whole process of decision-making are discussed, from the first suspicion that all may not be well with the state of the air to the final assessment of benefit obtained from abatement activities. The word " discuss " is used here to indicate that the almost infinite variety of circumstances surrounding air pollution problems make it quite impossible to suggest ready-made solutions to any specific problem. However, an attempt has been made to cover the general principles involved. There is always a communications difficulty between experts of one discipline and those of another. This chapter has therefore been prepared with the frontier between science and administration particularly in mind. It is hoped that sufficient examples are given to make the various points clear. Some of the options mentioned, both administrative and technological, are dealt with in much greater detail in subsequent chapters.

The order of presentation is first the treatment of existing pollution problems and then the avoidance of new problems. Two subjects stand somewhat outside this scheme—namely, problems of pollution arising from motor traffic, and pollution surveys; these topics are dealt with separately at the end of the chapter.

HEALTH AND AMENITY

The World Health Organization defines health as " a state of complete physical, mental and social wellbeing, and not merely the absence of disease or infirmity ". This means, in effect, that both health—in the usually accepted meaning of the word—and amenity must be taken into account in considering air pollution problems. In fact, air may be defined as being polluted when the concentrations of any of its minor constituents are sufficiently high to cause damage to the health of man or animals, or to cause loss of amenity through deposition of dust and dirt, emission of unpleasant smells, diminution of sunshine, and so on. To this list must be added environmental damage in the more general sense already mentioned (see p. 9).

A much greater number of people suffer severe loss of amenity than suffer ill health as a result of air pollution, and the present climate of opinion in many parts of the world is such that immediate action is demanded to put matters right, whether health or amenity is concerned. Pressures are still, perhaps, a little stronger when health appears to be affected, but the general public is often not entirely clear on the distinction between the two and tends to assume that there is a closer connexion between them than may, in effect, exist.

Amenity—identification of the problems

Air pollution is said to cause loss of amenity when it makes life less pleasant than it would otherwise be, without affecting health in the medical sense. Loss of amenity therefore requires no measurements to be made or pollution levels established. Specific nuisance in an area is apparent to any normal man or woman whose senses have not become dulled through fatigue or adaptation (hydrogen sulfide, for example, so affects the nerves in the nose that after a fairly short exposure people are no longer able to detect it by smell). Grit and dust, and the nuisance they cause, are obvious from visual inspection, but a case against them may be confirmed by a few simple measurements with a deposit gauge to show by how much the rate of deposit exceeds that in a normally clean area. Grit and dust do not travel far in the atmosphere before they are deposited, and in any locality the source of excessive deposition should be obvious without recourse to elaborate surveys with directional gauges.

Nuisance by malodorous emissions is also obvious and again confirmation does not need data obtained by measurement. " Nuisance " is a subjective concept and is not defined in terms of concentrations of specific substances. In any case, most of the evil-smelling substances complained of are exceedingly unpleasant at such low concentrations that chemical tests cannot be used for detection without the use of elaborate and expensive procedures. The best that can be done is to recruit a panel of observers with " educated noses " to report on the occurrence and severity of the smell, day by day—reports on bad smells by pharmacists and chemistry teachers from local schools, for example, are much more reliable than those from the general public. In this way it is sometimes possible to connect a smell with specific failures (leaks, etc.) at the plant from which it arises.

Loss of sunshine is in a rather different category because the cause may be general pollution originating outside the district. It is easy to obtain a continuous measurement of sunshine with simple equipment and to compare the results with those from a nearby, but less polluted, area. The comparison must be made under the guidance of a meteorologist, since sunshine can vary from place to place for reasons entirely unconnected with air pollution; for example, it is often sunnier at the coast than at an equally polluted place a little way inland.

The problem of amenity and its loss must be fully taken into account in all legislation against pollution.

Health—definition of the problem

Action to reduce air pollution on health grounds may arise in three ways—namely, from the occurrence of an incident followed by an increased death or sickness rate clearly attributable to air pollution, from the presence in a district of a factory from which dangerous emissions could emanate, and from the suspicion that the industrial and demographic structure of a district may be producing generally distributed pollution above acceptable levels.

The smog incident in London in 1952 is a classic example of an event that was followed by wise action. Long before 1952 it was realized that the average level of air pollution in London was high, but the extent to which pollution could rise above this average on days with particularly unfavourable weather, and the possible consequences of this rise, were either not well enough appreciated by the technical advisers concerned, or if they were, the advisers failed to convince the authorities of the urgent need to reduce pollution. On 4 December 1952 atmospheric stagnation under a temperature inversion set in over London and prevented natural ventilation of the city. These conditions lasted 4–5 days and pollution increased about 20-fold. As a result, some 4000 people—for the most part elderly sufferers from bronchial diseases—died sooner than could have been expected under normal conditions. This brought about a political demand for immediate action, which was strong enough to override the normal administrative caution that tends to delay action until the technical advisers are certain of all the relevant facts, even if such delay becomes indefinitely long.

It was not known which of the many pollutants that accumulated in the smog was, or were, responsible for the high death rate. Coal smoke was a likely candidate, but sulfur oxides or other pollutants could equally well have caused the trouble. It was possible on technical grounds to take rapid action to reduce the emissions of smoke without imposing much economic hardship, whereas it would have been outside the bounds of technical feasibility to take rapid action against oxides of sulfur, and even longer term action would have been economically impossible if more than a moderate degree of abatement had been attempted. In the event, a political decision was taken to deal with smoke immediately and this action was spectacularly successful. The health of bronchitics is no longer affected by the variations of pollution that occur in London as a result of meteorological changes. The lessons to be learned from this incident are that rapid action may be required without waiting for the technical advisers to cross every "t" and dot every "i", and that such action can be completely successful.

The next point concerns action in a district where particularly poisonous emissions might occur. Lead works may be taken as an example. If the dust-arresting equipment in the works is inadequate or not well maintained, dust containing lead compounds may be emitted. Some may fall in the immediate neighbourhood but the finer dust particles may remain suspended in the air. Arrangements should be made for a regular analysis of dust samples—both the deposited and the suspended material—and if the lead content of the dust rises unduly the lead content of blood samples taken from local inhabitants should be examined. For the same reason, analysis of dust samples should also be carried out on a regular basis around zinc smelters to see whether there is any emission of cadmium, and around asbestos works and works using beryllium. It is not sufficient to wait for ill health to become apparent in the community.

The remaining type of problem concerns the possibility that within a given urban area the general pollution levels may, at least on occasion, be excessive. Nowadays, much is known about the relationship of pollution levels to emissions under different weather conditions, and the results of detailed surveys are available for many different types of town. An experienced consultant should therefore be able to make a reasonable estimate of the pollution levels likely to occur, basing his judgement on a visual inspection of the industrial and residential structure of the town and its topography, and taking into account the climate of the region. If this estimate shows that undesirable concentrations of pollutants are at all likely to be approached, it should be checked by a short series of measurements at the most vulnerable site. There is no need to wait for a full-scale survey lasting for several years before starting abatement action. To insist on waiting for the results of such a survey can in fact be little more than a pretext for delaying action. A survey in sufficient detail to guide the application of an abatement programme and check its efficacy is an essential feature of such a programme and is dealt with later. However, positive abatement measures can be taken even before the results of a survey become available.

AIR POLLUTION LIMITS TO PROTECT HEALTH

It has been assumed in the previous section that limits for pollutant concentrations can be set to protect health. WHO has devoted a great deal of effort to defining such limits, and the situation was reviewed by a WHO Expert Committee in 1972. This section refers briefly to the general principles underlying the Committee's work, and their findings and the substance of their final report [a] is given in Chapter 3.

In all communities there is wide and continuous variation in the susceptibility of individuals to the effects of air pollution. At one end of the range, some healthy adults can tolerate relatively high concentrations of pollutants without suffering harm; at the other end are subgroups that are particularly susceptible; notably, the very old, the very young, and those affected by disease. At the far end of the range there will always be a few people who can tolerate no additional stress of any kind. Community protection is therefore a statistical concept, and in the context of this manual is taken to mean " protecting the vast majority of even the susceptible subgroups from significant harm ". To attempt a more precise definition is unrealistic. Another difficulty is that the medical evidence on the effects of air pollution on health does not provide administrators with unequivocal answers to questions about relationships between damage, exposure, and concentrations of pollutants. For practical and ethical reasons it is unlikely that this difficulty will be overcome in the near future. Decisions must therefore be taken now, if possible, on the basis of such evidence as is available.

The evidence indicates that very rough limits can be defined for the common pollutants, below which they appear to cause no harm. In general, these limits vary with the criterion and may, for example, be different for the exacerbation of the symptoms of bronchitis than for the incidence of asthmatic attacks. The limits will differ from one subgroup to another and may be influenced by climatic and other conditions. However, in spite of the uncertainties, the experts considered that available evidence does provide a basis for action.

Long-term goals

Although it is difficult to know what factors of safety should be applied to the concentration limits mentioned in the preceding paragraph, the WHO Expert Committee took the view that there must be a level between these limits and the usual background concentrations at which particular pollutants would be unlikely to produce any ill effects, and that such levels could be used as long-term goals. The Expert Committee made recommendations for sulfur oxides, suspended particulates, carbon monoxide, and photochemical oxidants [b] on the understanding that they should be revised when more data become available.

Short-term goals

The Expert Committee realized that for technical and economic reasons few, if any, countries could be expected to adopt the proposed long-term goals at the present time. The Committee therefore recommended that shorter term goals should be established for the immediate future. These short-term goals would be designed at least to prevent illness

[a] WHO Technical Report Series, No. 506, 1972 (*Air quality criteria and guides for urban air pollutants:* report of a WHO Expert Committee).

[b] See Chapter 3, p. 35.

and death in the susceptible subgroups. In setting short-term goals the report of the Expert Committee [a] should provide useful guidance. The data have been selected from a much larger body of evidence and are reasonably representative; if anything, the data selected are biased on the side of safety. Pollutants covered in the report include sulfur dioxide; smoke in the presence of sulfur dioxide; carbon monoxide; and photochemical oxidants. Although the Committee also discussed nitrogen dioxide, they found that there was insufficient evidence on which to base specific air quality guides at that time. However, taking all studies into account, it would now appear that adverse effects set in at a daily average concentration of about 100 $\mu g/m^3$.

Ultimately, the question of how much protection over and above a basic minimum is to be provided requires a political answer because all improvements in protection and accelerations of the programme increase the cost to the community. It may reasonably be expected, therefore, that the short-term goals will vary from country to country and, within any particular country, in the course of time.

Special pollutants

Reference has already been made to particular poisonous pollutants that may be discharged from certain factories. Many countries have issued lists of " maximum allowable concentrations " of these pollutants that must not be exceeded within the factories. Such lists are based largely on the United States industrial hygiene regulations. These concentrations were arrived at by assuming an 8-hour exposure for a healthy man for 5 days a week. Considering that the general population is exposed to air pollution for 24 hours a day and 7 days a week, and that both the very young and the old and infirm are equally exposed, atmospheric concentration limits for these special pollutants in the atmosphere should be much lower than factory limits; they are usually taken to be between 10 and 100 times lower, depending on the specific properties of the pollutant concerned.

ECONOMIC PROBLEMS

The cost of air pollution to the community has been emphasized by many authors. For the general pollution that now exists in many places over towns and countryside these arguments are not very convincing and it would be difficult to make a case for the reduction of air pollution on economic grounds. In specific instances, however, there may be a strong case for action. For example, action had recently to be taken in the Netherlands to limit emissions of hydrofluoric acid from fertilizer factories because important economic crops of flowers were being damaged. A careful watch should be kept on the need for this type of action.

[a] See Chapter 3.

TECHNICAL POSSIBILITIES FOR THE ABATEMENT OF AIR POLLUTION

In most instances of air pollution where action is required the necessary technology is available but its application may be costly; economic considerations will then become decisive. In some instances the best solution cannot be applied owing to lack of technology; the second-best technical solution, or sometimes an administrative one, then has to be adopted. The following comments on the possibilities of dealing with the different types of pollutant summarize the present state of knowledge.

Grit and dust

Serious pollution from grit and dust often results from winds blowing across fields without vegetation cover or over deserts, or is raised by motor traffic on roads where dust is allowed to accumulate. A considerable proportion of dust from industrial sources has its origin in bad " housekeeping "; that is, from factories with unswept roadways and piles of fuel and other materials used or produced by the factory left exposed to the wind. Remedies are obvious. Almost all other grit and dust comes from industrial furnaces, and there is no shortage of technical means for abating the nuisance. Such systems range from simple, cheap, settling chambers, through various types of cyclone arrestor, to large and expensive bag-filter plant and electrostatic precipitators. All these methods have been used for many years in a wide variety of plant, and it would, in general, be difficult to make a case that suitable dust-arresting equipment could not be used for economic reasons. Pollution of the atmosphere by grit and dust is not produced by domestic open fires or stoves burning coal or coke because the draught in the chimney is insufficient to carry particles of ash up from the fuel bed and out through the chimney mouth. However, oil-fired equipment for space heating may produce small carbon particles that can fall out over the whole neighbourhood if the burners are not properly designed and maintained in adjustment. Any oil-fired plant may produce smuts, which are often impregnated with sulfuric acid from the sulfur in the fuel, if the chimney is badly designed and allows condensation to occur inside the walls, thereby trapping carbon particles. Lumps of the trapped material become detached from time to time and are emitted as smuts. Again, the remedy is a simple one—namely, to insulate or redesign the chimney.

Smoke

There is no technical means of preventing the emission of smoke from open fires burning bituminous coal, which is often used for domestic heating, as in the United Kingdom, for example. The only means available for smoke abatement is the replacement of coal by solid smokeless fuels such as coke, or open fires by other forms of heating. However, as far as industry and the smaller boilers used for the central heating of buildings are concerned, modern plant efficiently operated produces smoke for only very short periods on starting up. If smoke is produced it is a sign of inefficient operation or that the plant is obsolescent. The solution is therefore an administrative matter, taking into account the economics of modernization.

Sulfur dioxide

Sulfur dioxide is produced when coal, coke, or oil is burnt, and two quite distinct problems arise. The first is to keep the ground level concentrations within such limits as may be considered tolerable from the point of view of health. The second is concerned with its putative effects on the environment generally; this is not merely a question of ground level concentrations but of the magnitude of the total emission.

Ground level concentrations can be controlled in a number of ways. The simplest, and perhaps the most effective, is to restrict the sources of energy used in vulnerable areas to those that do not emit sulfur dioxide at the point of use—electricity and gas, for example—and also to use low-sulfur fuels (coal or oil) that produce minimum emissions of sulfur dioxide. Reserving coals with a low sulfur content for towns particularly at risk generally involves increased freight charges to bring the coal from a distance, while low-sulfur oils are more expensive than average oils otherwise similar in grade. Nevertheless, this type of control has been used in practice without serious economic consequences. For example, low-sulfur coal was used by one of the large power stations in central London for many years to keep down pollution, and the restrictions that have been in force for several years on the sulfur content of oil burnt in the central districts of Paris do not appear to have caused economic hardship.

While all these procedures rearrange the emissions geographically to give the maximum protection to vulnerable areas they do not decrease the total sulfur dioxide emission over a country as a whole. If, however, the low-sulfur fuel required were obtained by partial desulfurization of average coals or oils these restrictions would also serve to reduce total emissions. A considerable reduction in the sulfur content of certain coals can be effected by normal washing techniques that remove some of the pyrites but cannot, naturally, affect the organic sulfur content of the coal. The normal operation of petroleum refineries involves a degree of flexibility that allows more lower-sulfur light oils to be produced at the cost of producing at the same time higher-sulfur fuel oils. It is technically possible to remove and recover a proportion of the sulfur and so reduce total sulfur dioxide emissions from the use of a given amount of crude oil. This is, in fact, practised to some extent. However, such processes become increasingly expensive as more sulfur is removed. In some instances it might be preferable to effect the desulfurization of coal or oil indirectly and reduce total emissions of sulfur dioxide by gasification and recovery of the sulfur from the gas before it is used as a source of power. The technology involved is well known and reliable.

The second type of method for controlling ground level concentrations of sulfur dioxide involves the removal of this pollutant from the flue gases before they are emitted from the chimneys of industrial plant. Such methods would have the added advantage of reducing total emissions. Ways of removing sulfur dioxide from flue gases have been under investigation for the last 50 years but of the many processes that have been proposed only one has been successfully operated on a full scale for a number of years. The flue gases are washed with very large volumes of water—some 20 tonnes per tonne of fuel burnt in the boilers—to which a little lime or chalk is added. Two such installations in central London have been in use for more than 20 years, but they are not popular on account of the cold, wet plumes of washed gas that descend on the neighbourhood where they cause worse pollution than if the flue gas had not been washed and had dispersed naturally. For this reason, one of these gas washers has recently been shut down. Several other gas-treatment processes are on the market but very careful assessment would be needed before any of them could be confidently recommended for a particular application. In general, the cost of processes for removing sulfur dioxide from flue gases is prohibitive unless they can be applied on a very large scale. This difficulty is overcome by a method in which combustion occurs in the presence of alkali to trap a large proportion of the sulfur. Coal or oil (or other solid combustible material) is burnt in a fluidized bed of sand to which powdered lime or dolomite is added as required. This method has been used successfully in quite small industrial plant.

The third possible course of action against pollution by sulfur dioxide is to use properly sited chimneys of adequate height and design for good dispersion of the flue gases. In this way it is possible to keep the ground level concentrations of sulfur dioxide as low as may reasonably be required. It should be noted that this is the only method that has been widely and successfully used for this purpose. High chimneys are never cheap, and when the height required is 200–250 m, as in large power stations, they are very expensive indeed.

The use of high chimneys to control ground level concentrations of sulfur dioxide has been criticized because the total emission into the atmosphere is not reduced and undue stress may be placed on the self-cleaning processes that occur naturally in the air. No evidence has yet been produced that these natural processes are failing to deal satisfactorily with the situation, but there is a possibility that in particular areas long-distance drift of pollution under special weather conditions may be adversely affecting lakes, forests, and soils, particularly lakes that are unbuffered and soils that are naturally acid, as in Scandinavia. An international investigation to study long-distance transport of pollution has been set up by the Organization for Economic Co-operation and Development (OECD) to see whether, on this account, there might be a need for international restrictions on emissions. The results are not yet available. It should also be noted that there is no indication that any harm is being done by the very low concentrations of sulfur dioxide that occur generally in the countryside as a result of drift of pollution from towns, but evidence about crop yields, etc., is scanty. Whatever the outcome of these investigations, and others that it may be necessary to make, it would seem that high chimneys, being very efficient in reducing ground level concentrations of sulfur dioxide, will continue to be used for this purpose, even if it is found that restrictions on total emissions are required.

Chemical fumes

With the present state of technology there is nowadays no reason to tolerate emissions of poisonous or unpleasant chemical fumes since they can be prevented without undue economic strain.

Malodorous emissions from the " offensive trades "

Perhaps the most unpleasant forms of air pollution that occur come under this heading and arise mainly from small establishments processing animal wastes, food residues, etc., and from intensive farming units; all of them can cause intense nuisance over very small areas. Great improvements can often be effected by strict insistence on high standards of " housekeeping " and by designing the plant so that the malodorous gases are contained as far as possible and passed through simple scrubbers or absorbers, or, if a boiler forms part of the plant, through a furnace. Owing to the small scale of the operations the problem is usually one of economics. The industries concerned are quite often connected with farming and the countryside, and re-siting the plant well away from housing is often possible.

LEGISLATION AGAINST EXISTING POLLUTION

It is well understood that a decision to enact or not to enact legislation against air pollution in any particular country is a political one that can only be made after many more factors have been taken into consideration. The main question will probably always be whether available resources could not be better used for housing, social services, medical care, etc. Assuming that legislative action is accepted, several general points have to be borne in mind.

The first point is that the law should be enforceable. This implies that the legislation is wanted by the general public, although it may go a little further than might have been wished. Basically, however, there must be agreement in principle between the legislators and those for whom they are legislating. The ground for new legislation on air pollution may have to be prepared by skilful presentation of the facts if long-established customs and behaviour patterns are threatened with change, as, for example, in the United Kingdom when the burning of coal in open fires for domestic heating was banned. In general, both in the domestic field and industry, modernization means less pollution, and wise legislation is legislation that is moving in the same direction as public opinion and acting as a catalyst to accelerate changes that would, in any case, have occurred. In many instances, in fact, the public demands faster progress towards clean air and becomes impatient with governments for what they consider to be their slow reaction, being unaware of the economic and technical difficulties involved.

The next point also has to do with the enforceability of laws, but from the technical rather than the political point of view. The object of all action against air pollution is the reduction of concentrations of pollutants in the air to values below tolerable limits. This should be clearly stated in the preamble to the legislation and the particular limits should be quoted. However, this is not enough; a law framed solely in terms of such limits is ineffective from the start because if the limits are exceeded it is impossible to know on whom to inflict penalties. The specific requirements of the law must be framed in terms of emissions that must not be exceeded. These emission limits should be chosen so that, in general, if the law is complied with, the ground level concentration goals set out in the preamble will also be attained. In this way it is easy to exact penalties where necessary because emissions from any suspected plant can easily be measured.

The final general principle is that it should be possible technically, and without undue economic hardship, to attain the legal limits of emission. In the past, the phrase " undue economic hardship " has been a source of misunderstanding and its significance is discussed later (p. 17) in connexion with the " best practicable means " for reducing emissions.

The remaining considerations have to do with the degree of flexibility that must be left in the law in order to be able to deal in the best possible way with the various problems that arise. In parts of Europe where there is a heavy demand for domestic heating in winter, much of the pollution experienced in towns may arise from this source. The total domestic emissions of pollutants may be less than industrial emissions, but the chimneys are much lower and the comparatively low temperature of the flue gases means that they have little buoyancy to help their dispersion. In the long term, district heating can solve these pollution problems, but in the short term pollution by smoke can be reduced only by using smokeless sources of energy—solid smokeless fuels, oil, gas, or electricity—and pollution by sulfur dioxide only by using oil with a low sulfur content, gas, or electricity. Since it is impossible to produce large supplies of fuels at short notice such changes cannot be imposed on a whole country, or even the urban areas within a country, all at once. Legislation has therefore to be framed to allow the changes to be brought in over a number of years. Arrangements must be incorporated in the law to ensure that supplies of these alternative fuels are reserved, as far as possible, for the towns most affected by pollution, and that action in any town is made dependent on the availability of these fuels. The detailed administration of such changes can be left to a greater or lesser extent to local authorities acting under the general supervision of the central government.

Pollution by existing industry presents different problems since the restraints are usually economic and concerned with the costs of installing and operating equipment to keep air pollution within tolerable limits. It is generally accepted that the polluting industry must itself bear these costs, but a few exceptional cases are referred to later (see p. 17). The difficulties are concerned with the framing of rules to govern emissions. For example, in the case of two identical factories, if one factory is located in the country and the other in a town, no restrictions of emissions may be needed for the first factory to keep the pollution level in its surroundings within acceptable limits, whereas severe restrictions may have to be imposed on the second, along with the other major emitters in the town, to keep pollution there within the prescribed limits. This action would adversely affect the ability of the factory in the town to compete effectively with its rival in the country. Alternatively, the same restrictions could be imposed on both works so as to leave them strictly competitive with one another but making them both vulnerable with respect to foreign competition not subject to this type of limitation. Work-people often prefer to tolerate a great deal of pollution rather than see a firm on which their livelihood depends forced to close down. Again, if there are several different kinds of factory in a town, as is usually the case, the application of fixed rules for controlling their emissions may affect them economically to very different degrees. It is often found that the worst pollution arises from obsolescent plant, and the limited useful life expectancy of such plant is another factor to be taken into account in deciding on the severity of restrictions to be imposed on its emissions. The problem may well be dealt with by imposing conditions to hasten the modernization of the plant concerned.

It seems clear that a high degree of flexibility must be retained in dealing with emissions from existing installations and that, in effect, every case should be considered on its merits. This has led to the principle used in the United Kingdom of enforcing the " best practicable means " of reducing emissions, which implies both technically and economically practicable. It is left to the discretion of a technical official to decide how " practicable " should be interpreted in each individual case. The words " economically practicable " and " without causing undue economic hardship " are very widely misunderstood. They do not imply that a token reduction of emissions is accepted for the sake of maintaining high profits. On the contrary, industry is forced to go as far as it can, short of losing its economic viability, towards reducing its emissions to a level where they are without effect on health and amenity. In many instances this goal is achieved. While this method of retaining the necessary flexibility has worked excellently in the past, misunderstandings have arisen from the way in which the law has been administered, since it has often not been apparent to the public that, as between themselves and industry, justice has been done. The method would be greatly improved if a decision on the degree of pressure to be applied in any instance were not left to the discretion of a single technical officer, acting in private, but were given to a small panel with both lay and technical members, acting in public.

PENALTIES AND SUBSIDIES

There have been many suggestions that those who pollute the air should be made to pay for so doing. In the view of the present author this would appear to be a very dangerous doctrine indeed as it bears the implication that wrong-doing is not so wrong if the doer can afford to pay. While this approach may encourage the reduction of emissions to escape the penalties, it does not positively enforce reductions, and in that way it seems inferior to other approaches that do so. It might perhaps be acceptable in principle if the total pollution level to which the plant concerned is contributing is low enough to cause no damage either to health or amenity, in which case a charge might be considered to be analogous to charging for the use of an existing sewer. Even then, the difficulty of assessing the burden imposed on the self-cleaning powers of the atmosphere by different types of emission makes the formulation of just rules almost impossible. If any detectable damage to health or amenity occurs, the problem becomes even more difficult because emissions causing such damage—low-level emissions from domestic heating, for example—may have much less effect on the atmosphere as a whole than high-level emissions that hardly reach the ground.

Subsidies can be used to make feasible the suppression of noxious emissions from particular plant. This is a sound procedure when it is in the national interest to keep the plant concerned in operation but the cost of installing and using equipment for abating the emission of pollutants would make continued operation of the plant uneconomic, and therefore impossible.

METEOROLOGICAL CONTROL

In any area the level of pollution to which the inhabitants are exposed represents a balance between the rate of emission of pollutants from chimneys and the rate at which these pollutants are blown away by the wind or dispersed harmlessly into the upper air. Mostly, the pollution is easily tolerated and becomes intolerable only on the comparatively rare occasions when the wind drops to calm and the vertical dispersion processes fail owing to the occurrence of a temperature inversion (i.e., the temperature of the air high above the ground is greater than it is just above ground level). If such conditions persist for a day or two, pollution concentrations may increase 10 or 20 times. Under such circumstances the position of a town surrounded by hills is particularly unfavourable since the hills also hinder the dispersion of the pollutants.

Most national meteorological services produce weather forecasts for the general situation to be expected in the next 24 or 48 hours. By concentrating their attention on particularly vulnerable areas they can forecast failures of natural ventilation of the type outlined in the preceding paragraph. It has been proposed that such forecasts should be the basis for shutting down large emitters that would contribute to pollution trapped below an inversion, or requiring them to reduce their emissions by using fuel with a lower sulfur content instead of the fuels normally used, or by other appropriate measures. Installations with very high chimneys—modern power stations, for example—may make no contribution to the level of local air pollution since the chimney mouth may be above the level of the inversion, or, if it is not, the thermal buoyancy of the flue gases may be sufficient to take them above that level to disperse freely in the upper air.

It is a very serious step indeed to close down a large modern works at short notice, and it would be foolhardy to do so unless, firstly, the forecasts were reliable, and secondly, the consequences of continued operation during a period of calm and temperature inversion were likely seriously to affect health. Some loss of amenity for a few days in the year should be acceptable if the cost of avoiding it is very high, but this is a political decision. It is doubtful whether meteorological forecasts of natural ventilation failures are by themselves sufficient for this purpose, but when combined with up-to-the-minute continuous recordings of pollution levels they can provide short-term (12–18 hours) indications that are probably sufficiently reliable to be used as a signal to burn low-sulfur fuels, bring special equipment for limiting the emission of pollutants into operation, or take preparatory steps for setting other emergency plans in motion if persistent heavy pollution does occur as predicted. Storage of stocks of low-sulfur fuels at some factories may cause certain difficulties, but these seem trivial by comparison with alternative measures.

However, perhaps the short-term forecasts are best used as a signal for broadcasting warnings to those suffering from bronchitis and other respiratory diseases to stay indoors, where pollution is always lower than it is outside. When such warnings occur in the winter, it is particularly important that no action should be taken, or recommended, that could result in elderly bronchitics being left without adequate heating in their homes.

PLANNING PERMISSION FOR INDIVIDUAL WORKS

Many of the principles involved in reducing existing pollution apply equally to the control of plant and housing not yet constructed. As already mentioned, many of the present-day pollution problems result either from obsolescent industrial plant or from the unplanned siting of plant in relation to residential areas. The replacement of obsolescent plant is a matter of economics, and therefore ultimately of political action. If replacements are properly made and supervised, the importance of this problem should rapidly diminish in the future. The siting of new plant must be made a matter for strict control if air pollution from industry is to be reduced to tolerable levels, or maintained within such limits.

The first rule must be that all proposed installations that could give rise to pollution should require planning permission. This rule should apply not only to the larger major emitters, but even to the smallest workshops engaged in the " offensive trades "—boiling pig food, drying poultry manure, processing animal wastes, etc. This rule should also apply to new central heating plant for commercial premises. Details of methods of dealing with planning applications in relation to air pollution will differ from country to country, but it is important that the responsible officials should be competent to consider, and if necessary refute, the expert evidence produced to support applications.

A planning authority will take into account certain general arguments when dealing with any application. Perhaps the most important of them is that, as a minimum requirement, the best practicable means (practicable economically as well as technically) must be used to reduce emissions of pollutants. It is wrong, in principle, to allow avoidable emissions of pollutants even though it cannot be proved that they are causing harm locally.

It is equally wrong, in principle, to allow factory after factory to be built in a particular area and so allow the total emission of pollutants to build up to a value approaching, even if still below, what may be considered as a safe limit, when through the use of planning powers, emission densities may be limited by the planned dispersal of industry. This touches closely on general town and country planning policy. Two examples illustrate the argument. A modern cement works with the best dust-arresting equipment should give little cause for complaint, but if, say, five such works are set up in the same neighbourhood the total emission of dust may be equal to that formerly produced by one works with an old-fashioned dust arrestment system. The great concentration of cement industry in the Thames Estuary in southern England is giving rise to concern in this respect. Again, while total emissions of sulfur dioxide in a given area may be less than those considered safe on medical grounds, there is a possibility that by oxidation sulfuric acid mist forms in the atmosphere and the emissions may thus be responsible for industrial haze and loss of sunshine. The wise use of powers under planning permission laws may be, in effect, an insurance policy against ill effects if it is found that existing tentative limits for pollutants have been set too high.

In addition to these general considerations, whenever planning permission is sought for erecting a works at a given site, estimates must be made of the pollution it is likely to cause in the neighbourhood. If the proposed site is in the country, where the existing pollution level is low, a greater increase in the pollutant concentration can be allowed than if the proposed site is in a more heavily polluted district, where a much smaller increment might raise the total pollution level to an unacceptable limit. The United Kingdom has for many years made provision for action along these lines by publishing official advice on chimney heights for new works necessary for keeping pollution within acceptable limits.

For a very large installation, such as an electricity generating station, with a chimney around 150–250 m high and standing on fairly level terrain, a good estimate of the pollution levels likely to be produced near the ground can be made by use of the empirical formulae developed by the United Kingdom Electricity Authority on the basis of their extensive experimental investigations. For rather smaller installations, say with chimneys up to 100 m high, the more familiar formulae may be used to obtain a sufficiently reliable estimate of pollution levels likely to be produced, as long as the chimney plumes are not affected by neighbouring buildings and the terrain is reasonably flat. A chimney plume is normally unaffected by nearby buildings if the chimney is at least two and a half times the height of the buildings; wherever possible, therefore, this rule should be adhered to. In many instances, particularly in towns, this is not always practicable. In such cases, and also when the terrain is not reasonably level, wind-tunnel tests must be carried out on scale models of the proposed works and their surroundings to estimate the pollution likely to be produced.

In making all these estimates the weather conditions over the district concerned have to be taken into account. Atmospheric stability, wind speed, and wind direction have the most effect on pollution levels. Calm, or near calm, weather is most to be feared because it is often associated with temperature inversions and greatly reduced natural ventilation, especially when the district under consideration is surrounded by hills. Coastal situations can also be unfavourable as alternating sea- and land-breezes can bring back pollution that has either drifted some distance out to sea or a little way inland.

Nowadays, when planning permission is sought for a works with a particularly obnoxious emission that cannot easily be reduced, the authority concerned has much more freedom than in the past to insist that the works should be sited an adequate distance from towns and villages. One reason for this is that modern means of transport allow the work-people to be housed much farther away from their work than was previously possible.

TOWN AND COUNTRY PLANNING

The problems of air pollution that have had to be dealt with up to the present time, and are still being dealt with, have arisen through lack of planning in the past. Even problems of planning permission for new works, as discussed in the preceding section, are more difficult and costly because they have to be solved within the confines imposed by earlier lack of planning. All remedial measures, and also planning within the framework of earlier neglect, are vastly more expensive than if care had been taken from the beginning, and the final results are often not nearly so effective. It is, therefore, of the utmost importance for the future that air pollution should be taken into account in all town and country planning schemes. The air pollution expert should be consulted at the very beginning, and his status should be equal to that of the architect, the transport engineer, and the economist. Even now, in many development projects air pollution is considered at so late a stage that irrevocable decisions affecting pollution levels have already been taken. Perhaps the most fundamental of these decisions concern the siting of new developments. The natural ventilation characteristics of any proposed site must be considered in conjunction with such factors as availability of labour, transport facilities, and so on.

In many existing towns and, unfortunately, in many towns still being built, one of the most important sources of pollution is domestic heating. With low chimneys and relatively low emission temperatures, the flue gases have little chance of dispersing satisfactorily and the streets can become heavily polluted. Nowadays, new houses should not be provided with the means of causing such pollution, and domestic heating should depend on fuels such as gas, electricity, or low-sulfur oil. If the housing development includes high-rise blocks of flats, high chimneys for district heating plant may be incorporated and concealed in these blocks.

The principles involved in designing the industrial sector of a new town have, in effect, already been discussed in the section on planning permission. They are the limitation of emissions to the greatest practicable degree, the possibility of having to limit the total emissions from a given area, the banishment of particularly noxious emitters into the country, and the use of chimneys high enough to keep the ground level concentrations of pollutants in the neighbourhood satisfactorily low. The design of high chimneys raises no difficulties on aesthetic grounds, as it would in a residential area, and assemblies of high industrial chimneys can be made eminently pleasing to look at; this is a challenge to the architects.

The industrial sector should be separated from the residential area by a *cordon sanitaire* or buffer zone of parkland and gardens, with as many trees as possible. Such a zone provides very large moist areas of leaf surface, soil, etc., to absorb pollutants that might otherwise drift across from the industrial zone. If particularly sensitive species of plants are avoided, the vegetation will not be affected adversely.

The question of the spatial relationships of the two parts of a town is not always a simple one. If the dispersion of pollutants were the same whatever the wind direction the residential areas would be sited on the windward side of the industrial zone in relation to the prevailing wind. In many instances, however, dispersion is worse when the wind is in some other direction. Expert meteorological advice should be taken on this problem for each particular proposal.

When a tentative design for a new town has been drawn up, calculations can be made to predict the pollution levels that would arise (a procedure known nowadays as mathematical modelling) on the basis of known patterns of emissions and the general weather conditions. The pollution picture obtained in this way for the area concerned should be reasonably correct, but prediction of actual pollution levels involves the arbitrary assignment of numerical values to certain constants. This is usually done by carrying out the same mathematical exercise for an existing town, situated similarly from a meteorological point of view, for which air pollution measurements are available. The constants are chosen so that the results of the calculation are the same as those obtained by measurement, and these values for the constants are used in the calculation for the projected town. This is, in fact, a rather refined way of using data obtained by measurement in one town to predict pollution levels in another. As a result of these calculations the tentative design may be found to need modification.

POLLUTION FROM MOTOR TRAFFIC

Pollution from this source becomes significant only under congested urban conditions when there is high traffic density. Two types of pollution can arise from motor traffic—pollution by lead and by-products of fuel combustion.

Tetraethyl lead is added to petrol to improve its combustion characteristics and to enable engines with higher compression ratios, and therefore higher efficiencies, to be used. Most of this lead is emitted as lead oxide dust in exhaust gases, and some of it becomes airborne. The dust can enter the lungs where it is absorbed into the body. Most lead in the body comes from food and drink and only a minor proportion comes from airborne dust; there is no evidence that lead from motor exhausts has ever been responsible for lead poisoning in man. However, since lead is a cumulative poison that is stored in the body, particularly in the bones, and can be released into the bloodstream under stress, it would appear prudent to limit its intake as far as is reasonably possible. This view is strengthened by measurements that show that the average intake of lead with food and drink is much nearer to—although still well below—the limit of safety accepted by WHO than is the case for most other poisons. Many countries are now taking steps to limit the amount of lead in petrol, but before such limits are set two points must be borne in mind. The first is that by using a low compression ratio engine, which will run satisfactorily on low-octane petrol, efficiency is reduced, more petrol is used for a given power output, and a correspondingly greater amount of pollutants from the combustion of the fuel is produced. The second point is that if refinery operations are altered to produce high-octane petrol without the use of lead, the cost is increased and the processes consume more crude oil than is used at present. More important, perhaps, is the fact that this kind of petrol will contain more aromatic hydrocarbons, which could increase the emission of carcinogens in the exhaust gases.

No technical solution to these problems appears to be available, or likely to become available in the near future. The only solution appears to be the administrative one of limiting the amount of traffic in city centres, and probably also limiting the size of engines of cars using city centres.

No satisfactory technical solution has yet been produced to deal with pollution from the combustion products of petrol-driven engines. The pollutants concerned are carbon monoxide, oxides of nitrogen, and unburnt and partially burnt hydrocarbons. Motor traffic is not the only source of carbon monoxide and oxides of nitrogen. Carbon monoxide is produced by the imperfect combustion of fuels in open fires and furnaces, and oxides of nitrogen by high temperature combustion processes, as in many boilers and furnaces. In congested, poorly ventilated streets motor traffic is the main source of carbon monoxide, which may be present at concentrations that could adversely affect people with cardiovascular diseases who have to breathe the polluted air for several hours a day. However, the amount of carbon monoxide entering the bloodstream of people living where there is dense traffic is less than that absorbed by people living in the country by smoking a few cigarettes. Oxides of nitrogen are much more toxic, and if their concentrations in busy streets were to increase sufficiently, steps would have to be taken to control them on health grounds. There is also an entirely different reason for controlling these emissions. In bright sunshine they react with hydrocarbons to give ozone and lachrymatory organic compounds, which together form photochemical smog of the type commonly experienced in Los Angeles, Mexico City, and some other places. This smog causes serious loss of amenity, and the oxidant concentrations can reach levels at which susceptible members of the population are affected. In many cities in Europe, motor car exhaust fumes can affect amenity on account of their nauseating smell. This may be due to partially burnt hydrocarbons (higher aldehydes) emitted in the exhaust gases, but the fact that the effect is at its worst on still, sunny days in summer might indicate that it is due to a precursor of photochemical smog. The high ozone concentrations observed under these conditions tend to confirm this view.

Nowadays most cars are fitted with crankcase blow-by devices, whereby the partly burnt gas that passes the pistons is not allowed to escape into the air but is returned to the fuel inlet manifold. This makes an appreciable reduction in the amounts of carbon monoxide and hydrocarbons emitted from the engine. In principle, it is not difficult to make a further reduction in these particular emissions by improving the combustion in the engine by using a weaker mixture of petrol vapour and air than usual, but this is only achieved at the cost of poorer engine performance and increased emissions of oxides of nitrogen. Carbon monoxide and hydrocarbons can also be reduced by completing the combustion by means of various types of afterburner after the gases have left the cylinders of the engine. The sensible solution, however, even if it is rather a long-term remedy, is to modify the design of the engine to produce an acceptable exhaust gas.

The problem of oxides of nitrogen is more difficult. Their concentration in the exhaust gas can be decreased by catalytic devices in the exhaust system, but this would require the use of lead-free petrol because lead rapidly destroys the activity of the catalysts. In any case, catalytic devices are notoriously unreliable outside the laboratory or works where the operating conditions can be kept under strict control. Again, the solution may come from improvements in engine design. It must be emphasized that even when a suitable modification has been devised and tested, manufacturers must be given several years in which to make the required changes in their production lines. Since legal requirements can only apply to new cars, reduction of the total amounts of these emissions in the streets will be slow, or very slow, if reliance is placed entirely on technical improvements. Thus the solution is again left to administrative regulations to control the access of traffic to city centres.

Gross pollution by diesel engines is due mainly to smoke and unburnt fuel, and these emissions can be almost completely prevented by correct maintenance and adjustment of the engine, although smoke is always emitted when the engine is started from cold. When running properly, the amounts of hydrocarbons and oxides of nitrogen emitted by diesel engines are about the same as those from petrol engines.

SURVEYS

The point has already been made that when there is gross pollution clearly detectable by the senses it would be a grave error to delay ameliorative action until the results of long and complicated surveys have been obtained. In less obvious cases of pollution, however, surveys will be required before action is taken, and surveys are always necessary for assessing the benefits accruing from such action and showing where action should be intensified and where it may be relaxed.

Surveys of air pollution fall broadly into two classes. In the first are those undertaken for administrative purposes, as outlined above. Such surveys may be short-term efforts made to compare the state of the air in one district with that in another, or long-term projects for assessing changes in pollution brought about by administrative action or in other ways. Long-term surveys must extend over a period of, say, 5–10 years in order that the effects of random changes of weather from year to year can be eliminated. Both long- and short-term surveys may be included under the term " monitoring ". In the second class of survey are those undertaken for research purposes, to investigate the effects of weather, topography, urban structure, etc., on the pollution pattern of a town, to study the drift and decay of pollutants, or to provide data for epidemiological research on the effects of pollution on health. The following paragraphs refer primarily to monitoring activities.

Before any monitoring system is set up, the basic questions of why the system is needed, how many data are required, and how accurate the data must be, have to be answered, and they must be faced in the knowledge that surveys are always very expensive, not only in terms of money, but also of trained manpower, the recruitment of which is becoming increasingly difficult. Moreover, in the past much effort has been wasted through the accumulation of unnecessary data that were never properly evaluated, or could not be evaluated. A new survey should be started in a simple way, and only if it becomes clear that the collected data are insufficient for the intended purpose should extensions and elaborations be introduced. Extensions of the survey would then be made in the light of experience gained from the simpler survey, and this will enable them to be designed in a much more practicable manner than would otherwise have been possible. It cannot be too strongly urged that the data obtained by a monitoring system should be sent day by day, as they come from the monitoring instruments or the analytical laboratory, to the central office for scrutiny. The project controller can then enquire at once into anomalies in the results of the previous day's observations. If this is not done, long runs of data of doubtful validity may be produced.

To clarify these points, the proposal to make an air pollution survey of a city for administrative purposes may be considered.

The first step is to carry out a rough emission survey. This is a simple matter because the emissions of pollutants from the larger works can be estimated from the fuel consumption, throughput of raw materials, and type of plant for each individual installation; for smaller industrial plant, large central heating plant, and domestic heating, estimates can be made for, say, each 0.5 km^2 of the city from deliveries of fuel, housing density, etc. (Rather more detailed emission surveys may be required at a later stage if the limitation of emissions has to be considered.) When these estimates have been obtained comparisons can be made with other cities that have similar emission patterns and are similarly situated topographically and climatically, where measurements of air pollution have been made. This will indicate whether a specific survey is necessary. If it appears that a specific survey is not required a few measurements should be made to confirm the validity of the comparison.

If there is no comparable city for which survey measurements are available, or the comparison shows that a survey is desirable, a survey should be started on very simple lines. There are no scientifically based rules defining the number of sites per km^2 at which observations should be made in order to obtain a sufficiently precise picture of the air pollution situation throughout a city. While various attempts have been made to construct such rules it is extremely doubtful whether they take adequate account of the difficulty of interpreting the meaning of " sufficiently " in the last sentence. It is almost equally difficult to take into account the high degree of variation resulting from the micrometeorology of the urban environment, i.e., variability in pollution levels from one side of a street to the other, from a point in a main street to another a short distance away in a side street, from the front to the back of a house, etc. In practice, the number of monitoring sites used in existing surveys is dictated solely by the financial and other resources available. Guidance in choosing the best locations for sites within the city can be obtained from a study of the pollution pattern obtained through the rough emission survey and the meteorological data for the area in which the town is situated. The results of surveys that have been made seem to indicate that, for the first year at least, 5 sites should be sufficient for a city of up to 250 000 inhabitants, and perhaps a few more in larger urban areas. These monitoring stations should be situated to measure pollution in the city centre, in the areas of dense, old-style housing usually found just outside the central area of a city, in the less dense modern housing towards the outskirts, and in the industrial area. Sites intended for monitoring general pollution should be chosen so as not to be directly affected by nearby emissions; for example, they should not be located over a busy road or directly in the path of smoke from a domestic or industrial chimney. However, if particular attention is being given to pollution from motor traffic, sites should be located in congested streets and, in particular, in streets in the city centre. The air intake for each instrument should, perhaps, be placed at head-height (i.e., breathing level) so as to record the pollution levels to which men and women are exposed. In practice, all this advice, and much more that could be given, is subject to the overriding requirement that the instruments should be installed where they are safe from vandals and where the operator has access to them every day. In effect, this virtually limits the sites to public buildings.

At least at first, measurements at these sites should be limited to daily observations of smoke, sulfur dioxide, oxides of nitrogen, and ozone, the last three being monitored by simple chemical methods. The chemical methods for oxides of nitrogen and ozone are not very precise, but they at least indicate whether there is a problem. If so, in the next stage, modern, but very much more expensive, equipment will be required, as described below, at a few strategic points. At each of the sites a monthly dust-fall gauge should also be operated.

As the pollution officer becomes familiar with the pollution pattern of the city he will probably decide that he needs further information about other areas. For this purpose, it will often be sufficient to make measurements at other sites for short periods to complete the details of the pattern; a mobile laboratory may perhaps be used for this purpose. Unless it is found that the original sites were badly selected, observations should be continued there over a period of years so that changes brought about by legislation or by modernization can be assessed. The important point is that the results of the first year's monitoring should be used as a guide for continuing observations.

One extension of the simple survey that is absolutely essential is to determine the peak levels of pollution concealed within the daily means, and how long these levels persist. This requires instruments to measure the concentrations of the pollutants continuously and to feed the results to data-handling equipment that can both print out the readings as they are taken and also store them for subsequent analysis. Such instruments cost a great deal more than simple daily reading equipment, often 10–100 times as much, and highly skilled staff are needed to operate them. Of the individual pollutants, carbon monoxide can be measured in this way most simply. The equipment is reliable and not too expensive; a number of recorders can therefore be installed in a town if it is considered to be necessary. One type of sulfur dioxide recorder is also fairly cheap and reliable, but other types of sulfur dioxide recorder on the market can be extremely difficult to maintain in working order. The continuous measurement of hydrocarbons, oxides of nitrogen, and ozone is also possible but the equipment needed is very expensive. However, it is reliable in the hands of skilled operators. Before any work is undertaken with any of these continuous recording instruments, they should be observed in operation in existing surveys, and estimates of the resources of all kinds required to keep them operating efficiently should be obtained from the users. A large city needs one set that can either be installed at a key site or moved from site to site as required. When observations have been made in a few places sufficient information may be available on the relationship between peak and mean pollution levels to enable expensive recording equipment to be dispensed with in other localities.

At least one survey has been set up to attempt to enforce a law that the ground level concentration of sulfur dioxide must not exceed certain limits. This requires the use of a large number of recorders in the area concerned, arranged in conjunction with wind recorders, to assess the contribution made by any particular factory.

Surveys of grit- and dust-fall are usually made to pinpoint an individual emitter and reinforce legal action to abate a nuisance. Gauges for this purpose are cheap, both in capital cost and operation; therefore, if it is necessary, many gauges can be used in the vicinity of the works concerned.

INVOLVEMENT OF THE GENERAL PUBLIC

Interaction between the public and government on air pollution matters has always existed but it changes rapidly. Many years ago, small, educated, sections of the public exerted pressure on governments to take action against air pollution, which was then hardly recognized as a danger by the population as a whole. Later, when governments were drafting legislation on air pollution they made use of various groups to prepare the way for the proposed changes so that they would be generally acceptable. In the United Kingdom, for example, the changes introduced by the Clean Air Act of 1956 were based on the abandonment of open coal fires for domestic heating, which were regarded with great affection by most people on account of their cheerful appearance. Replacement of coal fires by coke fires could have been very unpopular, and the lack of flames taken to imply that the fuel was inferior to coal in heating qualities. However, by the time the Act came into force, educated sections of the community so influenced public opinion that hardly any opposition was encountered on these grounds.

Since that time, conservationist ideas have spread widely, although most people are imperfectly informed about the details of the ecological balance. Governments are now subjected to intense pressures to take precipitate action on a whole range of environmental matters, long before the real issues have been understood by the public. Governments are accused of unnecessary delay when their greater knowledge counsels a cautious approach. There is now need for the dissemination of accurate knowledge throughout the population so that energy and enthusiasm for preserving the environment may be directed along channels where they are badly needed, rather than expensively misdirected. Societies organized by well-informed people concerned seriously with environmental problems have a most important role to play in this respect.

As stated at the beginning of this chapter, the object was to set out the options for action on air pollution for politicians and administrators, and to present the scientific and technical bases of the arguments in a simple manner. This chapter could, however, serve equally well as the synopsis of a programme of public education in air management.