Control of Air Pollution

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FOREWORD

by

Sir Hugh Beaver, K.B.E., LL.D.

It is over ten years since the notorious London Smog of December 1952 which finally led to the Clean Air Act and to the acceptance of clean air as national policy. No one who has ever studied the question, least of all the committee which reported in 1954, can ever have looked on the problem as anything other than complicated and difficult to a high degree. To achieve the objective of clean air, which in the submission of the Air Pollution Committee was to be taken as meaning air from which 80 per cent or so of the present contaminating solids had been removed or prevented, meant and means almost a revolution in the attitude of mind of the fuel user in this country, whether individual or industrial. It is easy to show that nationally speaking there would be immense savings in sickness and indeed in mortality, in misery and discomfort, and in money; the national bill that is annually paid, directly or indirectly, is certainly not less than £400 million. It is much more difficult to convince the individual that every one of the 52 million inhabitants of Great Britain is personally affected and concerned, in person and in pocket. But the Act has been passed, the objective has been declared, and nearly all responsible authorities, companies and individuals are now working to this one end.

It is inevitably a long and hard road before us and it is therefore of great value that there should be practical and broad studies of the main problems involved made available for those who are concerned with the general application of the Act. Such a textbook as this must be largely technical, but nevertheless it could be read with profit by the ordinary interested citizen. Since it has to range over a very wide field, it must inevitably leave the specialist to deal in greater depth with particular aspects—such as the highly difficult and indeed controversial matter of the economics and arguments of the size and siting of power stations.

There are, too, some of the problems to which the answer is not yet known, the ultimate hazard, for instance, of sulphur dioxide in a relatively clean air; or the cause of the much more serious sulphur trioxide. But we already know enough to make a really effective attack on dirt in the air, and this book should be of real assistance to those working in that field.

PREFACE

My purpose in writing this book has been to meet a long-felt need in the British public health service for a textbook dealing with the practical application of the Clean Air Act, 1956, and allied legislation. It has been written with the day-to-day requirements of Public Health Inspectors constantly in mind, as well as the needs of other local government officers. The book should prove of value to students preparing for the Diploma of the Public Health Inspectors' Education Board, the Smoke Inspectors' Diploma of the Royal Society of Health, and the qualifying examination for corporate membership of the Institute of Fuel. The book should also prove of interest to those in industry who are attempting to achieve higher clean air standards. Constructive comment on any aspect of the contents of this book, particularly from my former colleagues in the public health service, will be welcomed and appreciated.

For permission to reproduce diagrams and other material, I am indebted to the Controller of Her Majesty's Stationery Office, the National Coal Board, the Gas Council, the Central Electricity Generating Board, the British Standards Institution, the Coal Utilization Council, British Railways, and to the many firms and organizations whose assistance is acknowledged in the text.

I am most grateful to the following persons for reading and helpfully commenting on certain chapters: Dr S. R. Craxford and Dr M. Clifton of Warren Spring Laboratory (Chapter 2); Dr E. G. Ritchie (Chapter 13); Mr G. E. Stanley, Port Health Inspector, Manchester Port Health Authority (Chapter 17); Mr A. Ridgway, Chief Public Health Inspector, Wallasey (Chapter 22); Mr E. Rowden, Superintendent, Kiln Department, The British Ceramic Research Association (part of Chapter 25); Mr C. A. Adams, Chief Nuclear Health and Safety Officer, Central Electricity Generating Board (Chapter 27). Similar assistance has also been received from the following organizations: Messrs James Hodgkinson (Salford) Ltd (part of Chapter 7); the Esso Petroleum Company Ltd (Chapter 8); British Railways (Chapter 16); the British Iron and Steel Federation, the Joint Iron Council and the British Coking Industry Association (Chapter 24); and Messrs Leslie Hartridge Ltd (Chapter 28). For any deficiencies, however, I am alone responsible.

Much of what is said about power stations in this book (Chapter 26) was written before joining the staff of the Central Electricity Generating Board. The opinions expressed are my own and must not be taken as representing the views of the Central Electricity Generating Board.

Following the trend towards the use of the Centigrade (Celsius) scale for all purposes, with the gradual abandonment of Fahrenheit, temperatures have been expressed in both scales.

A. G.

Ascot, Berks.
July, 1963

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PART 1

AIR POLLUTION

1

THE NATURE, EFFECTS AND STATUTORY CONTROL OF AIR POLLUTION

In a strict sense, air may be considered polluted when there is added to it any substance foreign to its natural composition. This definition is rather wide, however, for the purposes of this book and the term 'air pollution' will be limited to those conditions in which the atmosphere contains substances in concentrations which are harmful, or likely to be harmful, to man or to his environment.

Some substances present in the earth's atmosphere which may, in excess, be regarded as pollutants are of natural origin. These include:

Ozone	Dust and gases of volcanic origin
Sea salt	Soil dust
Nitrogen dioxide	Bacteria, spores and pollens
	Products of forest fires

In Britain, one of the most important natural air pollutants is sea salt, or soluble chloride, which adds to the general corrosive nature of the atmosphere. Most of the pollutants with which this book is concerned are man-made, and include solids, liquids and gases. Combustion is the most important source of air pollution. Other sources are smelting and heating processes, mining and quarrying, cooking, chemical and nuclear processes.

Air pollution may become apparent in various forms:

(a) limited visibility
(b) damage to vegetation
(c) deterioration of materials
(d) strong or unusual odours
(e) visible grit deposits
(f) acid or unpleasant taste in the mouth
(g) irritation of membrane surfaces

Smoke is the most easily recognized air contaminant and contributes most to limited visibility. In this it is frequently assisted by nature which helps to create London's smog (smoke-fog), New York's smaze (smoke-haze) and El Paso's smust (smoke-dust). At the other extreme, traces of many air-borne toxic substances, or the presence of radioactive matter, cannot be detected through the senses at all. Pollution may simply be a source of nuisance, or it may contribute to or cause loss of positive health, actual injury and even death. Man's personal air filtration system is often ineffective against many forms of pollution.

The world's use of fuels is rising rapidly at present because of expanding industrialization; as a result the potential atmospheric pollution hazard is also growing. Table 1 gives an estimate of the weight of smoke, grit and dust, and sulphur dioxide discharged into the air of Britain in a year, together with the

Table 1. Estimates of Air Pollution from the Main Uses of Fuels in Great Britain in the Year 1960

(Figures are in millions of tons to the nearest 0·1 million tons)

This table has been prepared by Dr Albert Parker, Consultant, former Director of Fuel Research in the D.S.I.R. and is reproduced from the *Clean Air Year Book, 1962–63*, by kind permission of the National Society for Clean Air.

Fuel and Class of Consumer	*Quantity of Fuel*	*Pollutants Discharged*		
		Smoke	*Grit and Dust*	*Sulphur Dioxide*
Coal				
Domestic (including miners' coal)	34·5	1·1	0·1	0·9
Electricity works	51·1	small	0·3	1·5
Railways	8·9	0·1	0·1	0·3
Industrial and miscellaneous	48·7	0·4	0·3*	1·4
Coke ovens	28·5	small	small	0·1
Gas works	22·3	small	small	0·2
	194·0			
Coke (excluding consumption in gas works and blast furnaces)	13·2	nil	small	0·4
	—	1·6	0·8	4·8
Oil				
Domestic				
Kerosene and domestic fuel oil	1·5	very small	nil	very small
Industrial				
Kerosene, gas/diesel, fuel oil and creosote-pitch ..	23·7†	small	nil	1·2
Road and Rail Transport				
Motor spirit, gas/diesel, and fuel oil	10·3	small	nil	small
Marine Craft				
Gas/diesel and fuel oil ..	1·1	small	nil	small
	36·6‡	small	nil	1·2
Total for coal and oil ..	—	1·6	0·8	6·0

* Excluding grit and dust emissions, estimated at about 0·5 million tons from industrial processes other than steam raising.

† The amount of 23·7 million tons of oil is equivalent in thermal value to about 40 million tons of coal, which if used for the same purposes would have produced about 0·4 million tons of smoke, 0·2 million tons of grit and dust, and 1·2 million tons of sulphur dioxide.

‡ The amount of 36·6 million tons of oil is equivalent to about 62 million tons of coal, so that the coal equivalent of the coal and oil consumed (excluding air transport) in 1960 was about 256 million tons.

distribution of fuel consumption between classes of consumer. While the table is a valuable guide to emissions, it gives no indication as to the relative capacities of these substances to produce harmful effects. In addition, the conditions of discharge vary considerably from case to case.

Pollution in all these, and other forms, is continually being introduced into the atmosphere. If the atmosphere did not have certain self-cleansing powers, its condition would quickly become intolerable. Particles of sufficient size are removed from the atmosphere by gravitation. Smaller particles may be removed by impaction on the surface of the earth, or on buildings. The most efficient cleansing agent of the atmosphere is precipitation or rainfall. Raindrops efficiently collect and remove particles from the atmosphere; gaseous contaminants are primarily removed by absorption in the moisture. The character of pollutants may be modified by photo-chemical or chemical reactions which may accelerate or retard the effects of pollutants on man, beast or vegetation.

AIR CONTAMINANTS

Smoke

Smoke is a product of incomplete combustion. It consists of minute carbonaceous particles which remain suspended in the air until removed by precipitation or gravitation. The vast majority of smoke particles are less than 1μ in size and may only be examined in any detail by an electron microscope. Smoke from domestic dwellings is responsible for at least half of the total smoke emitted into the atmosphere. Distilled in the relatively low-temperature conditions of the domestic grate and consequently sticky and tarry in nature, it is discharged from numerous low chimneys often in meteorological conditions unfavourable to its rapid dispersal. It frequently eddies down to near ground level and becomes readily concentrated during periods of inversion. The emission of domestic smoke is largely confined to the winter months, and is especially heavy during very cold weather when the likelihood of fog is highest. Industrial smoke, on the other hand, contains very little tar and is discharged hot from high chimneys. Consequently, it is usually well-diluted before any of it reaches the ground. The emission of industrial smoke tends to be evenly spread throughout the year.

An investigation[1] carried out by the British Coal Utilization Research Association has established that 2·5–5·5 per cent of the coal burned in open domestic fires is emitted to the atmosphere as smoke. For typical chimney volume flows of 6,000–8,000 ft.^{3}/h at N.T.P., the smoke concentration is 0·05–0·15 gr./ft.^{3}. The amount of smoke is greater at low burning rates and with large refuel charges. For industrial appliances the weight of smoke emitted has been found not to exceed about 0·2 per cent of the fuel fired, even under 'dark smoke' conditions. This is about one-twentieth of the average domestic smoke emission. Industrial chimneys are, however, the principal source of grit and dust.

Recent studies[2] by the Department of Scientific and Industrial Research have indicated that:

(a) large towns are not necessarily dirtier than small ones;
(b) smoke pollution at any point is a more local matter than had been previously thought;
(c) smoke pollution depends on density of population and its coal consumption in a relatively small surrounding area;
(d) residents in a small town may well be exposed to smoke concentrations as high or higher than those found in large towns;
(e) smoke disperses generally more by moving in an upward direction through the turbulence of the atmosphere than by sideways drift near ground level.

Dusts

Dusts are solid particles produced in the course of combustion and processes such as crushing, grinding or demolition. Particles may be as small as 1μ in size. The most noticeable dusts and grits, above 76μ in size, while liable to cause a nuisance are filtered out in the nose and larger bronchi and do not penetrate to the depths of the lung. Only particles which are less than about 5μ in size, and scarcely noticeable, are capable of reaching the alveoli. This division between 'respirable' and 'non-respirable' ranges at a diameter of about 5μ is today widely recognized and forms the basis of mining regulations in Britain. The extent to which these particles are retained is partly dependent on their size. Lawther[3] has stated that the maximum retention in the alveoli is thought to occur when the inhaled particles are about 1·5μ diameter; the percentage retention falls when the particle size approaches 0·3μ. Cigarette smoke comprises particles of about this size. Calculations suggest that retention is again higher for still smaller spheres.

Diseases in industry arising from dusts include pneumoconiosis[4], silicosis, asbestosis and byssinosis. Many industrial dusts contain toxic substances such as arsenic, beryllium, cadmium, chromium, lead, manganese and selenium. Much has been achieved in controlling dust hazards in factories, foundries[5] and mines.

As far as the general public is concerned, the deposition of dust and grit in towns throughout Britain has been steadily decreasing[6] since 1955; the average rate of deposit has decreased from 141 to 121 mg/m^2/day. The rates of deposit at the majority of deposit gauge sites in 1958–9 were within the range 33–167 mg/m^2/day; less than a quarter of these had daily rates of more than the latter amount.

Gases

The number of individual gaseous impurities which can occur in a polluted atmosphere is enormous[4], the most important being as follows:

Nitrogen oxides	Aldehydes and ketones
Sulphur oxides	Organic and inorganic acids
Carbon oxides	Organic halides
Hydrocarbons	Ammonia

Special compounds specifically related to certain industries

Table 2 indicates the maximum permissible concentrations of gases and vapours sometimes present in industrial atmospheres. These values have been recommended by the Committee on Threshold Limits, American Conference of Governmental Industrial Hygienists, as maximum concentrations for continuous 8-hour exposure with no impairment of health or well-being. These standards do not provide any guidance as far as the general public is concerned. The general public includes the very young and the very old, the sick as well as the healthy, all of whom are exposed to pollution throughout much longer periods, though normally to much lower levels.

Nitrogen Oxides—Nitrogen oxides are emitted by practically all fuel-burning appliances. These oxides may be significant factors in air pollution; it is known that they play an important part in photochemical smog occurrences. Nitrogen

Table 2. Maximum Permissible Concentrations. (Average concentrations in parts per million by volume for a normal working day.)

The concentrations given are based on those formulated by the Committee on Threshold Limits of the American Conference of Governmental Industrial Hygienists. A full list is contained in the Ministry of Labour booklet, *Toxic Substances in Factory Atmospheres*, New Series No. 8, H.M.S.O.

Substance	*M.P.C.* (ppm)
Ammonia	100
Carbon dioxide	5,000
Carbon monoxide	100
Chlorine	1
Fluorine	0·1
Hydrogen chloride	5
Hydrogen fluoride	3
Hydrogen sulphide	20
Nitrogen dioxide	5
Ozone	0·1
Sulphur dioxide	5

peroxide may possibly influence the oxidation of sulphur dioxide in the atmosphere, leading to the formation of sulphuric acid mist[8]. Information is limited as to the amounts of nitrogen peroxide and nitrogen oxide present in the atmosphere due to the difficulty of measuring low concentrations of these gases.

Such tests as have been carried out have indicated that urban air contains nitric oxides and nitrogen peroxide in about the same proportions, and that the combined concentrations of the two gases varied up to about 5 pphm in summer, and up to about 10 pphm in winter. These results corresponded to about one-half of the concentrations of sulphur dioxide. Oxides of nitrogen appear, therefore, as major pollutants.

Sulphur Dioxide—Sulphur dioxide is a colourless gas, formed when sulphur burns in air. Dissolved in water, it forms sulphurous acid. Sulphur dioxide oxidizes in the presence of oxygen to give sulphur trioxide; combined with moisture this gives sulphuric acid. The toxic limit for some plants is less than 50 pphm[9]; the symptoms of attack are loss of healthy green colour and discoloration on leaf undersides. There are, however, many other contaminants harmful to vegetation such as hydrogen fluoride, hydrogen chloride, nitrogen oxides and hydrogen sulphide.

The toxic limit for humans is of the order of 500 pphm, with an 8-hour exposure. It is thought that the toxic limit is much lower in damp, cold weather, particularly in the case of persons with bronchial or asthmatic troubles. The ground-level concentrations of sulphur dioxide during the London smog of December, 1952, rose to a daily average of 134 pphm. The odour limit for sulphur dioxide is about 300 pphm.

The subject of ground-level concentrations of sulphur dioxide is highly controversial. In order to implement section 10 of the Clean Air Act, 1956, some standard must be adopted. This topic is discussed more fully in Chapter 20.

Carbon Dioxide—Carbon dioxide is produced when carbon is burnt in an ample supply of oxygen, and from other processes. It is a colourless gas with slight smell. Its toxic limit is extremely high, being about 500,000 pphm for an

8-hour exposure. About 170 million tons of carbon are burned each year in Britain, producing some 625 million tons of carbon dioxide. It frequently forms about 12 per cent of the flue gases emitted to the atmosphere; dilution by air quickly brings it below its toxic limit.

Carbon Monoxide—The amount of carbon monoxide in flue gases is normally very small save during periods of heavy smoke emission when it may rise to about 5 per cent. This poisonous gas may constitute as much as 15 per cent of the exhaust gases of a petrol engine. There are potential dangers from concentrations of this gas in streets congested with traffic, and in road tunnels; its presence is continually monitored in the Mersey tunnel. An investigation on air pollution in road tunnels has been conducted by the Medical Research Council Air Pollution Unit[10]. It was found that the concentration of pollution in the tunnels examined did not appear to be large enough to create special hazards for short exposures.

Fluorine—Fluorine is present in most flue gases, but presents a problem in only a few industries. In steelmaking, fluorspar is used as a flux, although fortunately the practice is diminishing. Brickworks and other branches of the ceramics industry also emit fluorine. Coals containing the highest proportion of fluorine are found in Kent, Staffordshire and South Wales. Chronic fluorine poisoning, or fluorosis, may occur in sheep and cattle grazing on contaminated pasture.

During 1956, court cases in the United States because of losses of livestock and crops due to fluorosis resulted in settlements amounting to over $50 million.

Beryllium and Selenium—Beryllium is used in crystalline form for transistors and in fluorescent lighting. In fabricated form, it is used for uranium slugs and small aircraft parts. As a fume, it is 250 times as toxic as trioxide of arsenic. Serious poisoning occurred when beryllium was first used industrially a few years ago.

Selenium has a use in the making of photo-electric cells. It is five times as toxic as arsenic, affecting particularly the lungs and trachea.

Benzpyrene—Benzpyrene is a hydrocarbon present in coal smoke and cigarette smoke. It is strongly suspected of being carcinogenic to man.

THE EFFECTS OF AIR POLLUTION

ILL-HEALTH

It is commonly accepted today that the presence of contaminants in normally inhaled air will tend to have a detrimental effect on health, either in the short- or long-run. There are certain instances where pollution has been diagnosed as the specific cause of an ailment, such as eye irritation brought about by Los Angeles and San Francisco smog, or chest diseases due to dusts in certain industries, but it has yet to be scientifically established that there is a close connection between air pollution and the general health of the population. There are, however, significant implications which most informed persons feel cannot be ignored.

Epidemiological studies have indicated that there is a correlation between high concentrations of atmospheric pollution and morbidity and mortality amongst chronic bronchitics. Such an association is not, however, an indication of a causal relationship. It is not easy therefore to ascribe individual deaths to air pollution, although during serious episodes of high pollution an excessive mortality rate occurs. These deaths are largely among the very old, and many are due to disease of the respiratory and cardio-vascular systems. The ultimate progress of these diseases is sensitive, particularly in winter, to many stimuli of which air pollution[11] is but one. It is considered reasonable to suspect that pollutants act mainly by virtue of their irritant nature.

Bronchitis—The Report of the Medical Research Council for 1959–60 states that:

(1) The recorded mortality rate from bronchitis in the United Kingdom is much higher than in any other country, and in middle-aged and elderly men is as much as 40 times greater than that reported in Scandinavia and the United States.

(2) At least 25,000 deaths are attributed to bronchitis each year, and the mortality rate, unlike that for pneumonia or tuberculosis, has not declined in the past twenty years with the general use of antibiotics.

(3) From an economic standpoint, bronchitis presents an equally serious problem. Approximately 10 per cent of all periods of absence from work are certified as due to bronchitis, which results in a total annual loss of over 25 million working days.

Chronic bronchitis remains such a bane of our national life as to justify the traditional title of 'the English disease'. During the past ten years, the crude death rate for bronchitis has never fallen below 55·9 per 100,000 in England and Wales. This figure applies to all forms of bronchitis, with chronic bronchitis accounting for the vast majority of them. Chronic bronchitis is not only a killing disease, but is one of the most crippling of the present day. This serious state of affairs is the result of a combination of factors:

(a) climate (it is relatively uncommon in dry, warm climates)
(b) size of community and density of population
(c) degree of industrialization and atmospheric pollution
(d) occupation
(e) smoking habits
(f) social class (housing, diet, medical care, etc.)
(g) size of family and overcrowding
(h) racial composition.

As a result of epidemiological studies on the relationship between air pollution and bronchitis, the Medical Research Council, in the 1959–60 Report, concluded:

'So far it has been impossible to discern any effect of atmospheric pollution on the earliest stage of bronchitis, largely because of the difficulty of distinguishing persons thus affected. But the effect of acute changes in atmospheric pollution upon the health of those with existing chest diseases has been abundantly demonstrated, even though the mechanism remains obscure.

'While much further research is needed, it is already clear that cigarette smoking and air pollution are two important factors in the causation of the disease. There is little doubt that effective measures taken against these hazards could prevent much of the ill-health, suffering, and premature mortality which chronic bronchitis at present inflicts on the population of the country.'

Lung Cancer—In 1960, cancer of the lung killed about 22,000 people; fifty years ago it was a rare disease. Cigarette smoking has been seriously incriminated as a cause of this disease; but there are still good reasons for suspecting that air pollution plays a part in this appalling state of affairs:

(1) Lung cancer is commoner in towns, than in rural areas[12] (the mortality of men in the 'truly rural' areas of Wales is only a quarter of that in the industrial conurbations)[13].

(2) Town smoke contains many substances which can cause cancer in experimental animals.

(3) Exhaust products of petrol and diesel vehicles contain small amounts of carcinogenic substances.

There is no evidence to support the view, however, that the exhaust products[11] of internal combustion engines have a hand in the matter. People who by their occupations are exposed to high concentrations of traffic fumes have shown no excess of lung cancer in their ranks. Nevertheless, on present evidence it seems probable that in Britain air pollution is responsible for a small proportion of the lung cancer in our midst.

In 1947, Stocks[14] advanced the hypothesis that 'smokiness of atmosphere is an important factor in itself in producing cancer of the lung', on the ground that the mortality in towns was inversely related to the amount of sunshine recorded. After several further studies, Stocks has now reported the results of work on the aerial content of four polycyclic hydrocarbons and thirteen trace elements[12]. In twenty-six locations ranging from Aberdeen to Newcastle-on-Tyne the mortality among men from lung cancer is shown to correlate to a high degree not only with the total smoke content of the atmosphere but also with the four hydrocarbons. Because of their common origin, each polycyclic hydrocarbon tends to be present in the air to a similar extent to the other three. Analysing the correlation, Stocks shows how, of the four, 3 : 4 benzpyrene is the most closely related to mortality. This hydrocarbon has long been recognized as a potent carcinogen in laboratory animals. It has also been identified in significant amounts in tobacco smoke.

The Report of The Royal College of Physicians on *Smoking and Health* (1962) confirms the conclusion that general air pollution appears to increase the incidence of lung cancer.

General Effects on Health—Air pollution is also damaging because it obscures natural light and this tends to reduce resistance to infection and retard recovery from illness. In evidence submitted to the Royal Commission on the Distribution of Industrial Population in 1938, the Registrar-General listed as one of the four factors most important in increasing urban death rates 'the production of smoke from factories and houses which reduces the effective sunlight'.

The amount of natural light received in an industrial area may be no more than half that received in rural areas, situated perhaps not far away, where the climatic and other conditions are similar. Many medical authorities consider this perhaps the most detrimental aspect of smoke pollution.

The psychological effects of reduced light and sunshine may be no less serious than the physical effects. The greyness, grime and gloom of a smoky atmosphere have a depressing effect. Dirt adds to the drudgery of the housewife —soot falls on washing hanging out to dry; windows and window sills are difficult to keep clean; soft furnishings, curtains and carpets tend to deteriorate more quickly. As Dr J. L. Burn[16] has expressed it:

'The particulate matter in air pollution defeats the housewives in their struggle to keep a good standard of cleanliness, takes toll of their time and temper, and eventually affects the emotional and physical health of the family in many ways.'

Effect on Animals

The effects of air pollution on domestic animals have been found to be similar to those observed in man; domestic animals were affected, for example, in the Donora incident of 1948. Mortality and morbidity occurred in cattle at the Smithfield Show in 1952 at the time of the London smog disaster, described below.

MAJOR AIR POLLUTION INCIDENTS

London

An association of fog and atmospheric pollution with increased mortality has for many years been a subject of comment by public health investigators. The fog which covered the Greater London area during the four days 5th–8th December, 1952, was on a much different plane to those previously experienced. It was accompanied by a sudden rise in mortality far exceeding anything previously recorded in a similar period of fog. The number of deaths of persons in excess of those which would normally have been expected during the first three weeks of December was between 3,500 and 4,000. On the evidence available at the time, it seemed that oxides of sulphur were the main irritants present. Subsequent analysis has revealed that between 80 and 90 per cent of the increase in deaths of persons during and immediately after the fog were due to respiratory and cardio-vascular diseases, mainly of a chronic nature. Over 90 per cent of the increased deaths were in people over the age of 45, and between 60 and 70 per cent over the age of 65. Deaths in children under one year were approximately doubled. Morbidity also increased. It was concluded[17] that it was impossible to state that any one pollutant was the cause of death, but that the irritants mainly responsible were probably derived from the combustion of coal.

Martin and Bradley[18], in a study of a subsequent fog incident in London during the winter 1958–9, have shown that there was a significant positive association between black suspended matter in the atmosphere and the daily number of deaths. They found a slightly less, but still significant association between sulphur dioxide in the atmosphere and deaths. They admit that '. . . the respective parts played by black suspended matter, by sulphur dioxide, and by purely meteorological factors remain a matter of conjecture'. Nevertheless, Martin and Bradley considered that, apart from exceptional incidents with very low temperatures, temperature appears to have a comparatively minor influence on mortality.

The Meuse Valley

The topography of the Meuse valley between Huy and Liège, a distance of some 15 miles is that of a steep-sided 'trench' about three-quarters of a mile wide and 400 ft. deep. The valley is densely populated and is a centre of heavy