First report / Royal Commission on Environmental Pollution.

ROYAL COMMISSION
ON
ENVIRONMENTAL POLLUTION

CHAIRMAN: SIR ERIC ASHBY

FIRST REPORT

Presented to Parliament by Command of Her Majesty
February 1971

LONDON
HER MAJESTY'S STATIONERY OFFICE
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THE ROYAL WARRANT

ELIZABETH R.

ELIZABETH THE SECOND, by the Grace of God of the United Kingdom of Great Britain and Northern Ireland and of Our other Realms and Territories QUEEN, Head of the Commonwealth, Defender of the Faith, to

Our Trusty and Well-beloved Sir Eric Ashby, Knight;

The Right Reverend Father in God William Launcelot Scott, Lord Bishop of Norwich;

Our Trusty and Well-beloved:

Sir Solly Zuckerman, Member of the Order of Merit, Knight Commander of Our Most Honourable Order of the Bath;

Sir John Winnifrith, Knight Commander of Our Most Honourable Order of the Bath;

Aubrey Leland Oakes Buxton, Esquire, upon whom has been conferred the Decoration of the Military Cross;

Wilfred Beckerman, Esquire;

Frank Fraser Darling, Esquire;

Neil Atkinson Iliff, Esquire;

Vero Copner Wynne-Edwards, Esquire,

Greeting!

WHEREAS We have deemed it expedient that a Commission should forthwith issue, to advise on matters, both national and international, concerning the pollution of the environment; on the adequacy of research in this field; and the future possibilities of danger to the environment;

NOW KNOW YE that We, reposing great trust and confidence in your knowledge and ability, have authorised and appointed, and do by these Presents authorise and appoint you the said Sir Eric Ashby (Chairman); William Launcelot Scott, Lord Bishop of Norwich; Sir Solly Zuckerman; Sir John Winnifrith; Aubrey Leland Oakes Buxton; Wilfred Beckerman; Frank Fraser Darling; Neil Atkinson Iliff; and Vero Copner Wynne-Edwards to be Our Commissioners for the purpose and with the powers following, that is to say,

to enquire into any such matters referred to you by one of Our Secretaries of State or by one of Our Ministers, or any other such matters on which you yourselves shall deem it expedient to advise:

AND We do by these Presents authorise you, the said Commissioners, to hold office respectively for a term of three years commencing from the date of this, your appointment, and to be eligible for re-appointment on the expiry thereof:

AND We do by these Presents authorise you to sit as a whole or otherwise for the purpose of inquiring into such matters as the said Sir Eric Ashby may deem expedient to allocate to you:

AND for the better effecting the purposes of this Our Commission, We do by these Presents give and grant unto you full power to call before you such

persons as you shall judge likely to afford you any information upon the subject of this Our Commission; to call for information in writing; and also to call for, have access to and examine all such books, documents, registers and records as may afford you the fullest information on the subject and to inquire of and concerning the premises by all other lawful ways and means whatsoever:

AND We do by these Presents authorise and empower you, or any of you, to visit and personally inspect such places as you may deem it expedient so to inspect for the more effectual carrying out of the purposes aforesaid:

AND We do by these Presents will and ordain that this Our Commission shall continue in full force and virtue, and that you, Our said Commissioners, may from time to time proceed in the execution thereof, and of every matter and thing therein contained, although the same be not continued from time to time by adjournment:

PROVIDED that, should you deem it expedient, the powers and privileges hereinbefore conferred on you shall belong to, and may be exercised by, any four or more of you:

AND We do by these Presents authorise you or any four or more of you to report to Us your proceedings under this Our Commission from time to time if you judge it expedient so to do, so however that you do not disclose in any of your reports material which in your opinion relates to confidential industrial information or techniques.

GIVEN at Our Court at Saint James's the twentieth day of February, 1970; In the Nineteenth Year of Our Reign.

By Her Majesty's Command.

James Callaghan

NOTE:

Frank Fraser Darling was created a Knight Bachelor in June 1970.

Neil Atkinson Iliff was appointed a Commander of the Most Excellent Order of the British Empire in June 1970.

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ROYAL COMMISSION ON ENVIRONMENTAL POLLUTION

FIRST REPORT

To the Queen's Most Excellent Majesty

MAY IT PLEASE YOUR MAJESTY

We, the undersigned Commissioners, having been appointed "to advise on matters, both national and international, concerning the pollution of the environment; on the adequacy of research in this field; and the future possibilities of danger to the environment";

And to enquire into any such matters referred to us by one of Your Majesty's Secretaries of State or by one of Your Majesty's Ministers, or any other such matters on which we ourselves shall deem it expedient to advise:

HUMBLY SUBMIT TO YOUR MAJESTY THE FOLLOWING REPORT.

CHAPTER I

INTRODUCTION

1. We were appointed on 20 February 1970 as a standing Royal Commission "to advise on matters, both national and international, concerning the pollution of the environment; on the adequacy of research in this field; and the future possibilities of danger to the environment". We have no specific or restricted task. We are authorised to enquire into any matters on which we think advice is needed, and also to enquire into any issues, which lie within our terms of reference, as may be referred to us by any of Her Majesty's Secretaries of State or Ministers.

2. We regard it as our function to find out what is happening to our physical environment and to inform the British public about trends in pollution and needs for research and development. We expect to propose ways to improve the quality of the environment through education, legislation, financial measures and international agreements. Our first task has therefore been to survey the field, with the help of Government Departments and other bodies, in order to decide where and how to make our contribution. We are grateful to the Trent River Authority and the Upper Tame Main Drainage Authority, as well as to the Water Pollution Research and Warren Spring Laboratories, for enabling us to see their work at first-hand.

3. In this brief preliminary report we summarise our conclusions. We begin by emphasising that a great deal has been done, and is being done, to safeguard the natural environment of Britain. Laws have been made to protect the quality of air and water and the cleanliness of the sea round our coasts, and to check litter and noise. Reports on several outstanding problems in preserving the environment have recently been published—we list the reports in an appendix—and other problems are still being studied by *ad hoc* committees set up by Ministers. Such bodies as the Noise Advisory Council and the Clean Air Council have been set up to watch over specific aspects of the environment. Scientific and technological research into the causes and control of pollution is being done by industry, in Government laboratories, and under the sponsorship of research councils. It is not our purpose to concern ourselves with work which is being effectively discharged by these other bodies.

4. But this record of action gives no ground for complacency. Avoidable pollution of air, land and water in Britain still goes on. Legislation often fails in its purpose not on account of inadequate laws, nor through lack of technical knowledge, but because the laws are not being enforced, sometimes through indifference but usually because those responsible are unable (or unwilling) to meet the costs of controlling pollution. Some anti-pollution measures have been brought in only as a response to public anxiety over grave dangers (such as the London smog in 1952), rather than as part of a comprehensive policy for protecting the environment. Some kinds of pollution are likely to overtake the present measures of control. The nation's resources for reducing pollution are limited; difficult choices will have to be made in their deployment. A standing

Royal Commission, which is independent of Government, has an opportunity to give objective advice on how these choices should be made and to contribute ideas toward a comprehensive policy for safeguarding the environment.

5. There is now a streamlined Government machinery for receiving this advice. The Government have brought together, in a single Department of the Environment under a Secretary of State, the former Ministries of Housing and Local Government, Public Building and Works, and Transport(1). The responsibilities of the new Department include the control of many aspects of air and water pollution and the abatement of noise, although of course the Scottish and Welsh Offices continue to play a major role in the areas under their jurisdiction. The Secretary of State for the Environment has taken over all the statutory powers of the three former Ministries and he is in personal charge of the new Department's co-ordination of work on environmental pollution(2).

6. The Department of the Environment does not, however, have responsibility for controlling all forms of pollution. The Ministry of Agriculture, Fisheries and Food, the Department of Agriculture for Scotland and the new Department of Trade and Industry, are among other Government Departments charged to protect the natural environment. And outside Government there are many voluntary associations—too many to catalogue without making invidious omissions—which perform an important service because they mobilise public opinion upon which, in the long run, political decisions depend.

7. Our strategy will be as follows:

(*a*) We shall select problems which require more attention than they are getting and, after enquiry, we shall recommend action by Government, local authorities, industry, or the public; and we shall, where necessary, draw attention to the need for research and development.

(*b*) When necessary we shall publish reports on some selected aspect of the environment, drawn from sources of information not likely to be accessible to the general public, or from investigations which we ourselves have commissioned.

(*c*) Where they have a bearing on our own problems, we shall make ourselves familiar with anti-pollution measures in other countries and suggest ways in which Britain should co-operate in international arrangements to preserve the environment.

8. In Chapter V we give our advice on the first problem referred to us by the previous Government shortly after our appointment: the need for further research on the effects of atmospheric pollution on weather and climate.

9. Many voluntary bodies and individuals have written to us about their local problems; accordingly we add here a note about one function which, in our view, does not lie within our terms of reference. We do not have the competence or the resources to act as environmental ombudsman, dealing with appeals against local or central Government decisions about specific cases of alleged damage to the environment where there are already channels through which such appeals may be made; what we are able to do is to give advice on the general principles which should guide Parliament and public opinion.

10. Another aspect of the total problem with which we do not think we should concern ourselves is the condition of the environment in which individual men and women live and work. This highly important problem is rightly the subject of a vast complex of legislation and public administration, as well as of activities by employers, unions and others; and recently a Committee was set up by the Department of Employment under Lord Robens to consider the provision made for the safety and health of persons at work. We therefore propose to limit our considerations to what might be called the "external environment", although we have made arrangements to keep in close touch with the work of Lord Robens' Committee.

11. There are three considerations beside straightforward pollution which vitally affect the quality of the environment. One is increase in population; another is the spread of derelict land. The third is the impact on the countryside of society's continuing drive to improve the standard of living. If recent trends were to continue the gross national product would roughly double by the year 2000. Apart from any increase in population this would mean more industry, buildings, roads, airports and reservoirs. These in themselves are not "pollutants" but, without adequate planning, their overall effect could be a grave deterioration in the quality of the environment which would outweigh the benefits of efficient anti-pollution measures. Nothing less than a comprehensive policy for the environment will suffice.

CHAPTER II

THE PROBLEM EXAMINED

Why there is a pollution problem

12. The problem we face is how to strike a balance between the benefits of a rising standard of living, and its costs in terms of deterioration of the physical environment and the quality of life. In the past the danger of polluting air, water and land was not fully recognised, but now there is no doubt that it is a matter of great concern. And as for noise, large numbers of the British public have reached the limits of their tolerance and demand that they should be protected from this sort of disturbance, especially noise from aircraft and traffic. Freedom from these nuisances is as much valued by some people as are clean air and clean rivers.

13. Economic and technological achievements over the last generation have been considerable: they have brought immense and worthwhile benefits to millions of people. But the benefits have often been bought at the cost of a deterioration in our physical environment; and the public realise this. Concern about pollution is mounting not only because some of its effects are becoming more evident; it is also because certain other social needs have been increasingly satisfied, so that concern about the environment has moved up in the list of priorities. Society has also become increasingly aware that economic output is not an end in itself: it is only a means to promote human welfare. Unless appropriate policies are adopted some forms of output can be pushed beyond the point where they make a net contribution to human welfare.

14. It may well be asked why it is that there should be a growing conflict between economic and technological advance on the one hand, and the quality of the environment on the other. There are two main reasons. One is rooted in a basic law of nature: it is impossible to add to the material resources with which the world is endowed and impracticable to dispose of waste materials outside the world and its envelope of air. Industry transforms natural resources and in doing so depletes some of them and spoils others—for example, our water resources—as a result of the undesirable accumulation of waste products. The second reason for the growing conflict is largely economic. Little can be done about the first reason, for even the most powerful legislatures cannot change the laws of nature; but many things can be done about the second. Governments can protect the environment through legal and institutional arrangements.

15. The economic reason why society may not strike the right balance between economic output and the quality of the environment is that the costs of many kinds of pollution are borne not by the polluters, but by somebody else. As a result these "external" costs will not, in general, be taken fully into account by firms, individuals or other bodies who cause pollution. The other side of the coin is that those who spend money on reducing pollution may not always be the people who gain from the resulting improvement in the environment. This applies both to "tangible" pollution, such as the poisoning of fish in polluted waters, and to "intangible" pollution, such as unpleasant smells or ugly landscapes.

16. This characteristic of pollution has three main consequences:

(*a*) Output of goods and services which give rise to pollution tends to be pushed beyond the socially optimum point. Also, expenditure to reduce pollution will often be inadequate. This is true not only for private firms or individuals: it is true also for public authorities. For example, it is hardly surprising that a large proportion of the many sewage works in this country are inadequate, since it may well be that the benefits from better installations—in the form of cleaner effluent and hence cleaner rivers—would be enjoyed only by communities living further downstream. In such cases all the benefits are external to the sewage authority, which therefore has little inducement to improve its plant.

(*b*) There is generally not enough incentive to reduce the amount of pollution per unit of output of the goods and services responsible, so that not enough resources and effort are devoted to this objective. For example, if it becomes cheaper to distribute milk in plastic containers instead of glass bottles, this will be done whether or not the production and disposal of plastic containers impose higher pollution costs per unit of milk consumed than does the use of glass bottles. It is true, of course, that technological innovation in some industries has reduced the amounts of pollution per unit of output; for example, the switch from coal to other resources of fuel over the last two decades has greatly reduced the amount of certain kinds of airborne pollution per unit of industrial output. But this benefit to the environment has been fortuitous; we cannot rely on technological innovation automatically to reduce environmental pollution.

(*c*) Insofar as pollution costs are not borne by those who cause pollution or by the purchasers of their products, but by people who happen to be the victims of the pollution, some of the total welfare resulting from the economic activity of the community is being redistributed away from the victims of pollution in favour of other groups in the community. Manufacturers whose production gives rise to pollution make greater profits than they would if they were obliged to bear the full social costs of their production, and purchasers of their goods buy them at a lower price than they would if the price had to cover the full social costs involved. Therefore both manufacturers and purchasers gain at the expense of other members of the community who may suffer in one way or another from the pollution.

Pollution abatement versus other claims on resources

17. None of this implies—as is often believed to be the case—that all forms of pollution must cease. All production involves some costs, whether they are borne by the polluter or are external costs borne by others; but this is not a reason for stopping all production: £10 of external costs are no more costly to society than £10 of the normal costs of the labour or capital that are used by firms in the ordinary course of business. The fact that some pollution costs are not borne by those who make or purchase a product merely reflects the particular institutional arrangements of society. Consider, for example, the costs of purifying polluted water: these costs would be no less if sewage authorities and the users of rivers were united in some common body (as they are not at present) so that the costs

were incurred by the same body which was responsible for the pollution. Similarly, the fact that airline operators do not have to pay to soundproof the homes of people who live near airports, is merely the result of particular legal and institutional arrangements and does not mean that the costs to society of the necessary soundproofing are any greater. Alternative legal or institutional arrangements could, in principle, be made to ensure that the costs of pollution caused by noise did enter into the calculations of the polluters like any other production costs. These costs would then play their full part in determining how far society should go in reducing pollution, and would no doubt lead to less pollution, other things being equal. But the costs to society of any given reduction in pollution would not necessarily be affected.

18. Thus, the problem which has often to be faced is not how to stop pollution altogether, but how far it should be reduced. One implication of paragraph 16 is that some productive activities have been pushed too far, not that they should cease altogether. To abolish all such activities, and hence deprive society entirely of their benefits in order to eliminate one particular form of social cost, would be a clear case of throwing the baby away with the bath water. Another implication of paragraph 16 is that inadequate attention and resources are likely to be devoted to reducing pollution per unit of output, not that there is no limit to the amount of resources which should be devoted to this end. The more we spend on abating pollution the less we have available for other desirable expenditures.

19. The social benefits of cleaner air and water, less noise and a more pleasant landscape, have to be put into perspective with other claims on resources, such as housing, health and education, or private consumption and investment. Nobody would suggest that the allocation of resources amongst these uses should be based on an "all-or-nothing" approach. For example, it would hardly be suggested that health has some absolute priority over all other social needs. Ideally we might all like to have pure water and complete freedom from noise and dirty air; but in practice we might tolerate some shortcomings in the environment in the interests of having, say, better schools, or better health or cultural facilities than we now enjoy. So long as resources are limited, choices have to be made between alternative ways of using them. There is no social merit in making exaggerated claims for one particular form of expenditure to the detriment of others which, to many people, may be more important.

The criteria for choice

20. The basic criterion for deciding how much to spend on abating pollution can be stated as follows. First, pollution should be reduced to the point where the costs of doing so are covered by the benefits from the reduction in pollution. This criterion is easy to state in these general terms but its application raises immense difficulties which are discussed in paragraphs 23–24.

21. Secondly, the choice that has to be made is not only between pollution in the aggregate and all other uses of resources; it is also between various kinds of pollution. And in making this choice one must not embark indiscriminately on some hastily devised crash programme to deal with emergencies, though specific local crises do occur from time to time as with the "Torrey Canyon"

disaster. What is needed is a careful prediction of the long-term ecological effects of various kinds of pollution, together with a sober analysis of their short-term impact. But there is no time to be lost in trying to determine priorities, since improvements in the environment take a long time to achieve. It has taken many years and millions of pounds to reduce smoke and sulphur dioxide in the air; it will require many years and millions of pounds to improve the standard of effluent which flows into some of our rivers. It must, however, be recognised that pollution is to an extent indivisible, in that it is unwise to try to deal with any one form in isolation. For example, it may be undesirable to solve a water problem and as a result put contaminated solids or sludges on the land, or to deal with solid waste or refuse by incineration and pollute the air. The possible side-effects of anti-pollution measures need careful study.

22. Thirdly, since relative costs enter into the choice between different forms of pollution abatement, this choice does not depend simply on which forms of pollution appear to be the most "undesirable". For example, the fact that—as is shown later in this report—most kinds of air pollution have been declining in Britain over the last decade, does not mean that it is not worthwhile trying to achieve further reductions in air pollution; for it might well be relatively cheap to do so. Conversely, some other form of pollution may be much more offensive, either now or in the longer run, but the costs of obtaining a given improvement may be so high that society would not be prepared to divert resources in order to obtain a substantial reduction in this particular form of pollution. In short, both sides of the cost and benefit calculations have to be taken into account.

Costs and benefits

23. Clearly, decisions concerning the degree and nature of pollution control and abatement require, in principle, comprehensive calculations of the costs and benefits involved. But we must state at the outset our view that there is no completely scientific and objective means of arriving at such decisions. There are three main reasons for this:

(*a*) There are great practical and theoretical difficulties in measuring all the costs and benefits of reducing pollution.

(*b*) Even if all these difficulties could be overcome and all the data on costs and prices collected, acceptance of these data as "true" measures of the relevant social costs would involve ethical rather than scientific judgments and they would be influenced in conflicting ways by different aspects of our present legal, political and social framework.

(*c*) As implied by paragraph 16(*c*) above, an important consequence of measures to reduce pollution will be that some people will lose while others will gain. It is true that distributional effects of this nature are likely to follow from almost any economic measures, but the special nature of pollution costs, that is, their "externality", is such that the distributional impact of measures to combat pollution is likely to be larger than usual and hence to have important political and social implications.

24. But the difficulties of obtaining precise scientific measures of the relationship between the costs and the benefits must not provide a pretext for failure to

analyse individual pollution problems as carefully and quantitatively as possible. The fact that no simple or mechanical cost-benefit exercise will provide all the answers does not mean that such analysis is not an important ingredient in the decision-making process. It is often the only way to ensure that all the main relevant variables are brought to light and to demonstrate the consequences, both direct and indirect, of alternative measures to deal with pollution. Moreover, the difficulties, formidable as they are, should not prevent us from reaching decisions about the scale of abatement of pollution which is socially desirable.

25. Nevertheless, although we must begin with quantitative estimates, we end with value judgments. In this country we have been spending thousands of millions of pounds a year on education, health and other social services without having first established exactly how far the measurable benefits from these expenditures exceeded the costs. We see no reason why a civilised society, which has already accepted the need to provide a fair standard of living in other respects, should not now willingly incur expenditure on the protection of its own natural environment. Decisions in this field will, of course, reflect society's value judgments in the same way as have decisions in many other fields of social and economic policy over the ages. A cost-benefit analysis of the abolition of slavery might well have shown that slavery should have been preserved; nevertheless, slavery was abolished.

The responsibilities of Government and the individual

26. Finally, we should like to distinguish between the different types of contribution to the control of pollution which have to be made by Government (including local authorities) and by ordinary individuals. As regards the former, we have already explained that one of the major causes of excessive pollution is that, given existing legal and institutional arrangements, the free market has not so far provided an adequate mechanism for ensuring that pollution is kept within socially optimum bounds. Changes in these legal and institutional arrangements are the province of Government. What form Government intervention should take is, of course, a matter for careful consideration and will be the subject of proposals which we expect to make in subsequent reports. In some cases, new regulations and controls may be required; in others it may be better to use fiscal methods or similar devices to ensure that polluters bear the costs of their pollution; in yet other cases it may be preferable for public authorities directly to provide the means of pollution abatement. But one contribution which Government can make will be to stimulate a wider understanding by the public of the pollution problem and a more active public interest in its control.

27. Although some forms of pollution can be controlled only by Government or by the efforts of industry, responsibility for reducing a great deal of pollution rests with individual citizens. The best insurance for the environment is a commitment on behalf of the public to prevent the deterioration of air, water and land. This is not to make any unique demand. If the only limit on crime were the official sanctions of law and order, and not the fact that the vast majority of the population are honest, social organisation as we know it could hardly exist. Most British households are of course obliged to dispose of effluent into the drains and rubbish in the dustbin; but noise, smoke from open fires, litter and

abandoned cars and household equipment left in streets and countryside, are forms of pollution which should be reduced by individual action.

28. There are simple ways in which individual men and women can discharge their responsibility. For instance, they can help to generate a sense of public hostility to litter, by their own efforts and by supporting voluntary associations; they can where necessary encourage their local authority to spend more money (which they themselves will have to pay in rates and taxes), for example, on the improvement of sewage disposal; they can co-operate in the conversion from open fires to cleaner forms of heating even though open fires are an agreeable tradition of British homes.

29. It is a counsel of despair to suppose that the public will not shoulder its responsibilities, in the same way as it does in many other aspects of social behaviour. Equally, it is the duty of Government and voluntary bodies to create a climate of opinion which will elicit this response. But protection of the environment cannot rest with individual citizens alone. For the reasons already given many kinds of pollution cannot be regulated except at the level of local authorities or central Government. Public opinion must be mobilised in such a way that elected representatives regard themselves as trustees for the quality of air, water and the landscape. We consider it an important principle that no one should have *uncontrolled* right to get rid of smoke, gases, effluents or solid wastes. It has long been recognised that in the public interest pollution of the environment with some of these waste products must be controlled or forbidden. What we have to achieve is a combined operation between public opinion, economic incentive and legislation.

CHAPTER III

THE STATE OF THE NATURAL ENVIRONMENT

Introduction

30. A sense of responsibility for the natural environment is not new in Britain, although there is still an immense amount to be done before we even overcome the physical depredations left by the industrial revolution. What is needed now is a comprehensive policy for restoring and safeguarding the environment. This must be based on hard facts, estimates of cost-effectiveness, and some assessment of what the public need and are prepared to pay for. Enough is known already to justify immediate action to deal with some kinds of pollution. More facts are, however, needed before dealing with others.

31. Hence, there are two kinds of priorities in this context:

(*a*) **Priorities for action.** These are issues on which the Government have already received, or will shortly receive, authoritative advice and on which prompt action is needed. Examples are the state of some of our sewage systems and the control of noise from aircraft and motor vehicles.

(*b*) **Priorities for enquiry.** These are issues which require further scientific, technological, sociological or economic enquiry before satisfactory policies for the control of pollution can be worked out. One of our tasks is to indicate which these issues are; this we do in Chapter IV.

32. Distinction between these two categories of priorities is not, of course, as clear-cut as this. The criteria interact: political and administrative decisions have to be made on an assessment of the balance between the need for a quick decision, the costs and benefits flowing from the decision, and the feasibility of a decision in the present state of scientific and technological knowledge. The first step in arranging an order of priority is to decide whether present trends in pollution imply what our terms of reference describe as "future possibilities of danger to the environment". In this chapter, therefore, we give a brief summary of some trends in the natural environment of Britain insofar as they concern pollution. Prognosis of the future based on trends from the past is always open to doubt, but such projections—even though events may prove them to have been false—are a useful rough guide to what may happen. In any case we have no other guide.

Population

33. Pollution is as old as civilisation, but it is now causing anxiety in all industrial nations, due to the growth of population and the spread of technology. Advances in public health and agriculture have lessened the two great constraints on population: disease and hunger. Demographers believe that it took about 1700 years from the beginning of the Christian era for world population to double; that it doubled again in the 150 years from 1700 to 1850; and that it will probably double again from its present level in the next 35 years. That is

why any comprehensive understanding of the problems of pollution must take account of the much larger problems of population. Technological change, too, has not taken place at a steady rate but has been accelerating.

34. There is no simple relation between pollution, population and technology; but as Britain's population and the gross national product rise between now and the end of the century, more energy will be used; there will be more transport; and there will be more waste to get rid of. No one can predict accurately what our population will be by the year 2000. One recent careful forecast for the United Kingdom is about 66 millions, an increase of 18 per cent over the present figure of 56 millions. But, for forecasts of the dangers of pollution, population growth is not the main issue facing our nation. More important are the concentrations of population in cities and in certain geographical areas in Britain, and the output per head which accompanies a rise in living standards: on a conservative estimate this output could well double over the next 30 years.

35. Failing deliberate measures to control pollution and to repair past damage, there is likely to be a substantial deterioration of the environment in the years ahead and the quality of life in Britain will be correspondingly impoverished, despite an appearance of greater affluence. It is against this background that we now summarise trends in the more important indices of pollution.

Air pollution

36. There is a long history of legislation to diminish air pollution in Britain; but for our present purpose we illustrate the trend in air pollution from data collected since 1950. Since the first Clean Air Act became law in 1956 there has been a steady reduction in the emission of smoke and sulphur dioxide into the air over Britain, despite a 10 per cent increase in population and a 17 per cent increase in annual gross energy consumption. This is clear from the data summarised in Figures 1–4, based on information obtained from the National Survey of Atmospheric Pollution, which is being carried out jointly by the Warren Spring Laboratory and a number of local authorities. One welcome result of smoke control has been the improvement in the atmosphere of our big cities; in Central London, for example, winter sunshine has increased by 50 per cent and is now virtually the same as at Kew (Figure 5)(3). But it must be emphasised that these improvements are not uniformly spread over the country. There are regions in the north of England where there is urgent need for a more vigorous application of the Clean Air Acts. We quote from a publication of the Warren Spring Laboratory:

> "The question posed by this position is whether with existing knowledge and legislation the North can be made as free from smoke as the South. . . . By the vigorous application of the domestic provisions of the Clean Air Act, and the changing social framework, the great housing estates of outer London have been made as free from smoke as any urban areas in the South and the inner core of Central London is within striking distance of achieving the same state of cleanliness in spite of its very high population density. This is not something that can only be achieved in the South because the data for Sheffield, a great industrial town in the North, show the same spectacular progress".

37. A significant point is the change over the last 20 years in the relative amounts of smoke emitted by industry, railways and domestic households. In 1953 a little more than half of the smoke put into Britain's atmosphere came from domestic chimneys, while one-third was contributed by industry and the remaining one-sixth by the railways. Fifteen years later in 1968, domestic chimneys caused about 80 per cent of the pollution due to smoke. The change-over from steam to diesel and electric locomotives has virtually eliminated railways as a source of smoke. These changes are illustrated in Figure 1 which summarises the relative importance of homes, industry and railways as smoke producers in 1953, before the Clean Air Acts were introduced, and in 1968.

38. The downward trends in smoke and sulphur dioxide pollution are encouraging, but they will continue only if there is no relaxation in applying the provisions of the Clean Air Acts and the Alkali &c. Works Regulation Act. Adequate supplies of the right fuels should be made available. Initially, solid smokeless fuel will remain important, but in the longer term there will be greater reliance on other sources of energy, notably natural gas, and eventually nuclear power. This should ensure that levels of smoke and sulphur dioxide in the air continue to decline. Nevertheless, this decline will be from levels which may be imposing very high costs on society in one form or another: the mere likelihood of future improvement does not necessarily imply that measures to accelerate the improvement are not called for.

39. The pollutants emitted by road vehicles include carbon monoxide, hydrocarbons, oxides of nitrogen and lead. There is no firm evidence that in Britain the present level of these pollutants is a hazard to health, even in busy city streets, although smoke from diesel engines can be very offensive. However, more needs to be known about the effects of long-term exposure to the various components of exhaust fumes at the relatively low concentrations at which they occur. This knowledge will be especially important if we are to deal rationally with pollution from the substantially increased number of vehicles which the Road Research Laboratory predicts may be on our roads over the next 40 years (Figure 6)(4). According to this forecast, the number of vehicles will increase from 16 million in 1970 to nearly 40 million in 2010—an increase of 140 per cent. With present engine design and fuel quality, the pollutants emitted by these vehicles in the year 2010 would increase to some 14 million tons of carbon monoxide per year (as against 6 million tons at present), as well as large quantities of the other components of exhaust fumes(5). However, a considerable research and development effort to reduce pollution is taking place between the motor vehicle manufacturers and the oil companies. Good planning should reduce traffic congestion and no one can be certain that vehicle numbers will continue to grow at the same rate as over recent years. But it would be dangerously complacent to ignore the potential implications of the trend indicated in Figure 6.

40. All the available evidence, both in this country and abroad, indicates that aircraft make a minimal contribution to total air pollution. Nevertheless, research is continuing on ways to reduce the pollution caused by aircraft, and engines of the future can be expected to emit substantially less smoke than those currently in service.

Long-term effects of air pollution on the climate

41. Carbon dioxide is one of the main products of nearly all kinds of combustion and there is evidence that it is accumulating in the atmosphere. Estimates of the carbon dioxide produced by the burning of fuel in the world since 1860 are summarised in Figure 7. It has also been claimed that the haziness of the atmosphere is increasing because of the dust and smoke created by agriculture, forest fires and industry; that the water vapour content of the upper air is being altered by high-flying aircraft; and that rocket exhaust fumes may add chemicals normally rare or absent in the stratosphere and so upset its fundamental chemical processes. We deal more fully with these matters in Chapter V of this report.

Refuse disposal on land

42. **Domestic waste.** An estimated 14 million tons of domestic refuse are collected annually and disposed of by local authorities in England and Wales, most of it by tipping on to unused, or unusable, areas of land. This amounts to about 2 pounds per person per day, compared with something over 4 pounds in the U.S.A.(6). The amount of refuse produced per person does not seem to have changed very much over the past few years, but some observers believe that it may increase substantially in the future. The overall figures have to be interpreted with care: the amount of refuse varies according to the season and the type of dwelling (for example, blocks of flats with central heating and garbage grinders produce less and different refuse from that produced by private houses with open coal fires). Moreover, the density of solid wastes changes with changing social conditions. The amount of ash and cinders put into the dustbin is about half what it was a generation ago, and the amount of paper three times as much. The following table compares the average composition of domestic refuse in the United Kingdom (1966) with roughly corresponding data from one source in the U.S.A. (1965):

Composition of domestic refuse (percentage by weight) estimated from a source in the U.S.A. and from the average of estimates in the U.K.(7):

	U.K.	U.S.A.
Cinders, ash, coal dust	35–40	10
Metallic waste	5–8	8
Glass	5–8	6
Vegetable and animal matter	10–15	12
Paper	25–30	45
Miscellaneous	0–20	19

Future trends are likely to be a diminution in waste from solid fuel fires and an increase in metal containers, paper and plastics. In the U.S.A. the per capita disposal of paper and tinplate is about one and three-quarter times what it is in the U.K. The future trend in the U.K. is likely to be similar; this means that there will be much more waste to get rid of. The treatment and disposal of domestic waste will therefore present increasingly difficult problems unless new methods are devised.

43. Modern industrial society is very wasteful. We extract, refine and fabricate materials at great cost only to use the products once and then discard them. Much more attention must be paid now and particularly in the future to the reclamation of valuable materials from domestic and industrial waste. Already some local authorities are able to salvage some ingredients of domestic and trade waste, such as metals and paper, and the incineration of the residue can be used as a source of energy. New processes for re-cycling materials are being studied in the Warren Spring Laboratory. In the long term the fuller development of these processes should avoid needless waste of resources and reduce the demand for land on which to dump rubbish.

44. The dumping of massive and durable pieces of junk, like the hulks of old vehicles and abandoned kitchen equipment, has become a nuisance. This debris is a menace to the farmer, destroys amenity, and costs money either to the individuals or the local authorities who have to clear it up. This problem cannot be allowed to expand in parallel with growth in the number of vehicles in service or increase in the total amount of household equipment produced. Dumping of waste in this way is already illegal and prosecutions are brought from time to time, while all local authorities have established and advertised the existence of tips to which people who are not prepared to incur the cost of a special collection can bring bulky objects for disposal. The solution appears to lie in the further development of the current threefold approach of legislative penalty, improved public services and increased public awareness.

45. **Industrial waste.** Excluding colliery waste or ash from power stations, slightly over 11 million tons of solid and semi-solid industrial waste were discarded in Britain in 1966(8). Over 10 million tons of this material were relatively inert. About 600,000 tons were acidic, caustic, or indisputably toxic: about half of this was in the form of slurry (the weights cited include its water content) which was pumped into settlement lagoons; a further quarter was disposed of in surface tips; and the remainder dealt with either by dumping at sea or in quarries and mine shafts, or by incineration. Almost all solid toxic waste was disposed of by tipping, minor quantities being incinerated or discharged into the sea.

46. A Technical Committee on the Disposal of Solid Toxic Wastes has published a disquieting review of the handling of these materials(8). One of the main problems identified in this review is that these wastes may contaminate rivers or underground water supplies. This could be a major hazard, since about one-third of Britain's supplies of drinking water is abstracted from underground and a further third comes from lowland river systems. So far, surface rivers and streams have been polluted much more frequently than subterranean waters, and there appear to be important natural barriers to pollution of underground waters from tips, but these natural barriers cannot be relied on for all wastes. The situation is made the more serious because the total volume of industrial waste which needs to be disposed of is growing from year to year, and an increasing amount is at present being dumped as an oily or aqueous chemical liquid sludge on ground where its containment cannot be guaranteed. Special problems can also arise from the dumping of oily and tarry wastes.

Pollution and agriculture

47. The common waste materials from the agricultural industry are: the residues of the special chemicals used to protect plants against disease and pests and to treat seeds; any surplus of fertilizer which is not taken up by the crop but leached off the land into rivers and lakes; and a proportion of the excreta of farm animals, particularly in intensive farming, which is no longer being returned to the land as manure. In paragraphs 48 to 52 we consider each of these waste materials in turn.

48. **Pesticides.** Pesticides have proved of great value both in the control of insect-borne diseases of man and in the protection of crops and livestock. They are used in homes, shops and industry as well as by farmers, foresters and gardeners. Most products in use were developed during the past 30 years, and demand continues to grow, particularly in developing countries where increased crop protection is essential to feed expanding populations and to earn foreign exchange. Unfortunately, there have undoubtedly been frequent cases of excessive use.

49. But it is common knowledge that the good effects of pesticides can be offset by dangers to the natural environment. To examine these dangers, the Advisory Committee on Pesticides and Other Toxic Chemicals in 1969(9) made a thorough and objective appraisal of organochlorine insecticides (such as D.D.T. and dieldrin). The Committee found that the persistence of these substances may cause harm to beneficial insects, such as bees, to fish, birds and other wild life. Also, organochlorine compounds tend to accumulate in fatty tissues, appearing, for example, in milk and meat, and to build up to lethal amounts in birds and animals which come near the end of the "food chain", although there is no evidence so far that this build-up constitutes any threat to human health.

50. The question of statutory control of the use of these pesticides is one we raise in Chapter IV, paragraph 77. The Advisory Committee stated "we are of the opinion that it is prudent to lower residue levels wherever possible" and "we consider it undesirable that the human environment should contain substances capable of producing toxic effects and whose continuous presence conveys no benefits". These are the main reasons why the Committee recommended voluntary restrictions on the use of organochlorine pesticides. The effect of these restrictions, which date back to earlier reports of the Committee issued in 1962 and 1964, is demonstrated by a decline in the use of organochlorine insecticides in England and Wales from 460 tons in 1963 to 300 tons in 1967. (There was a corresponding reduction in the U.S.A. from 60,000 tons in 1963 to 44,000 tons in 1967). At the same time the amounts of D.D.T. and dieldrin in human fatty tissues in the U.K. have continuously declined during the late 1960s.

51. **Fertilizers.** The amounts of artificial fertilizer applied to the land in Britain have increased considerably since 1940(10). Since 1968 the quantities used on arable crops have remained much the same, but increasing quantities of nitrogen are likely to be applied to grasslands in future. These fertilizers are generally retained efficiently by the soil and the crop, but some nitrate is liable to be washed out, especially if it has been carelessly applied to arable land in a wet spring, and this can have undesirable effects on rivers and lowland lakes, to

which we refer in paragraph 57. On the whole, however, this problem is contained in this country by good farming practice.

52. **Intensive farming.** In Britain an estimated 12 million cattle, 7 million pigs and 127 million poultry spend all or some of their lives indoors. In traditional husbandry livestock manure is spread on both arable land and pastures, and thus gives rise to no problem of pollution. But during the past 25 years our livestock population has not only increased considerably, but an increasing proportion of it has been kept under intensive conditions. The number of poultry, for example, about doubled between 1946 and 1968 and the number of pigs more than trebled in the same period(11), and most of them are kept in intensive units. Buildings in which cattle and pigs spend most of their lives are commonly hosed down with water; as a result the manure is removed as a wet slurry which it is uneconomic to carry to the land and, if it is deposited there, can readily wash or seep into drains and streams and pollute them. A pig produces as much organic material as three people, and a cow as much as sixteen people. If this material is not returned to the fields, valuable fertilizer is wasted and there is a risk of soil deterioration; moreover special provision may have to be made for its treatment either on the farm itself or at the local sewage works. What is needed therefore is some economic inducement to farmers to use manure from intensive farming.

Freshwater pollution

53. In their natural state, most rivers and lakes are rich in dissolved oxygen and support a great variety of plant and animal life. Many rivers in Britain are still like this. But pollution, especially by sewage and industrial effluents, and to a lesser extent by the run-off from farmland, has seriously affected others.

54. Sewage affects a river in three ways. First, it adds intestinal bacteria which have to be screened out if water is abstracted for domestic use. Secondly, and this is especially so if it is combined with industrial effluents, sewage may add toxic residues including metal salts, cyanides, "hard" detergents (which cause the river to foam), or residues of persistent pesticides. Thirdly, sewage contributes organic matter, some of which stimulates the growth of organisms which may use up the available oxygen in the water. If this happens fish and other living creatures are killed and the river may even stink.

55. The relation between polluted water and disease has been known for a long time and successive Governments have been at pains to ensure that the public have access to supplies of clean water. A recent report(12) quoted observations made in an informal survey by the Inspectorate of the then Ministry of Housing & Local Government. This survey covered 20,025 miles of rivers with a dry weather flow of at least one million gallons a day—which is roughly equal to half the volume of water which flows at 3 miles per hour in a channel one foot wide and one foot deep in the course of a day—summarised the position as follows:

	Miles	*Percentage of total*
Unpolluted or recovering from pollution	14,603	73
Doubtful and needing improvement	2,865	15
Poor and urgently needing improvement	1,279	6
Grossly polluted	1,278	6

FIGURE 1

Smoke emissions in the UK for 1953 and 1968, with a prediction for 1975

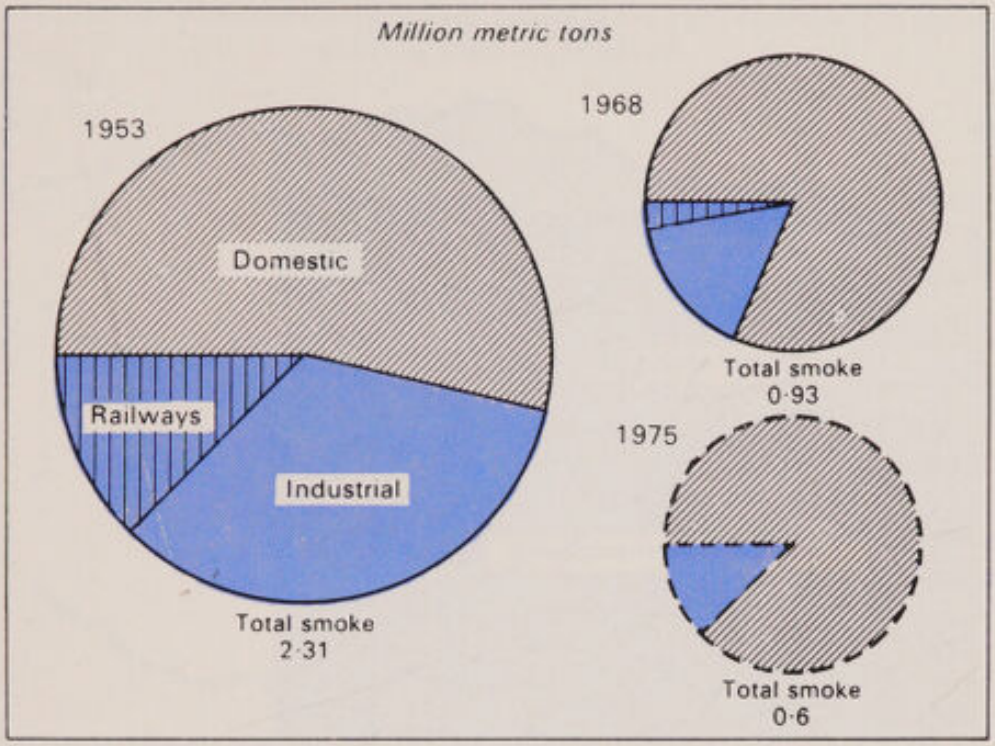


FIGURE 2

Average smoke concentration near ground level in the UK, 1958-1968

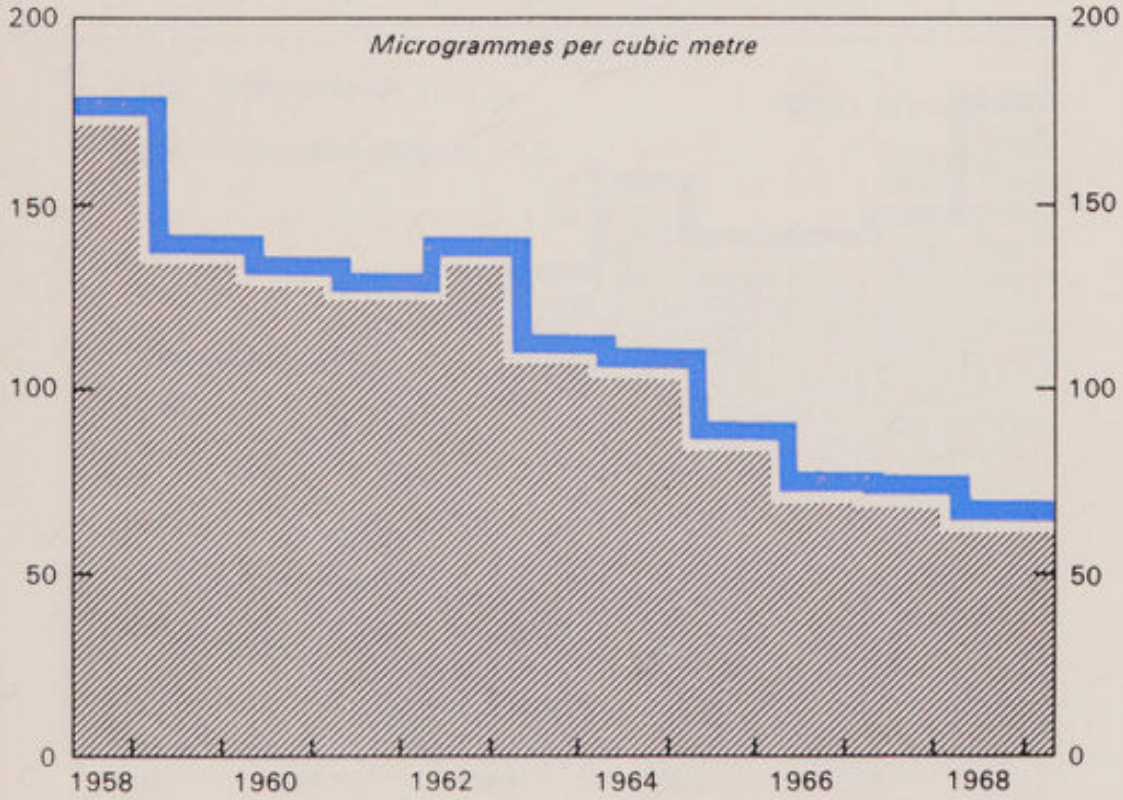


FIGURE 3

Sulphur dioxide emissions in the UK, 1950-1968
(with prediction to 1975, based on *Fuel Policy* – Cmnd. 3438, 1967)

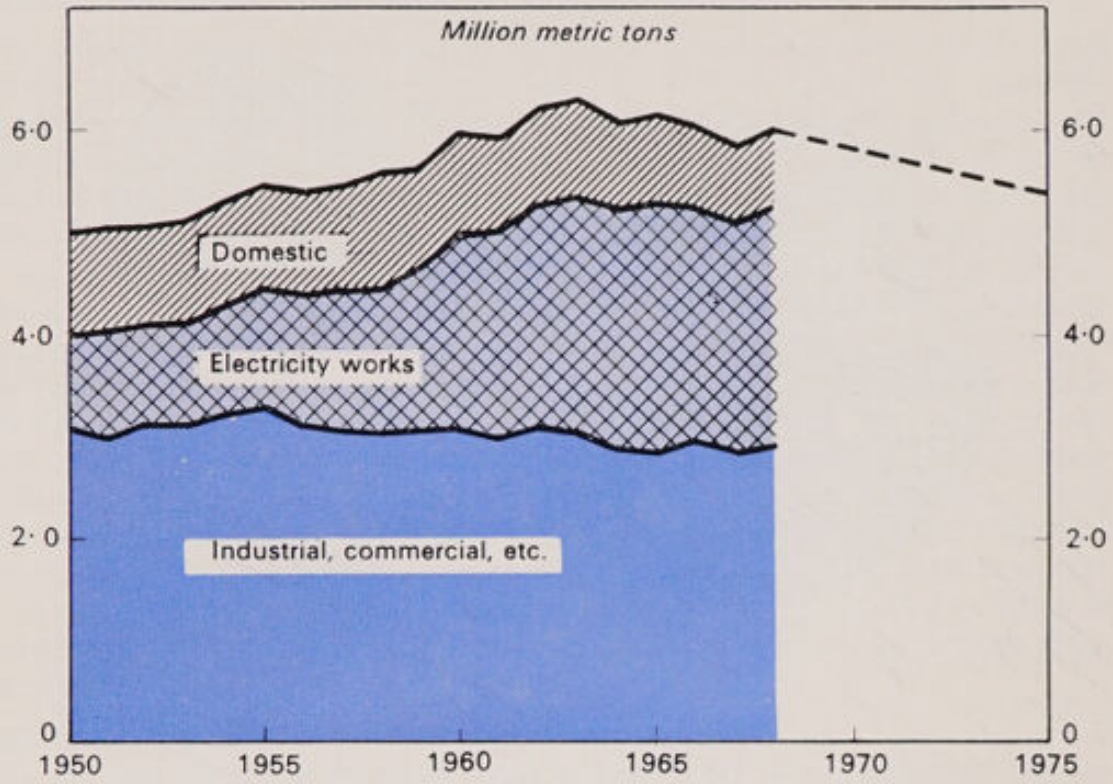


FIGURE 4

Average sulphur dioxide concentrations near ground level in the UK, 1958-1968

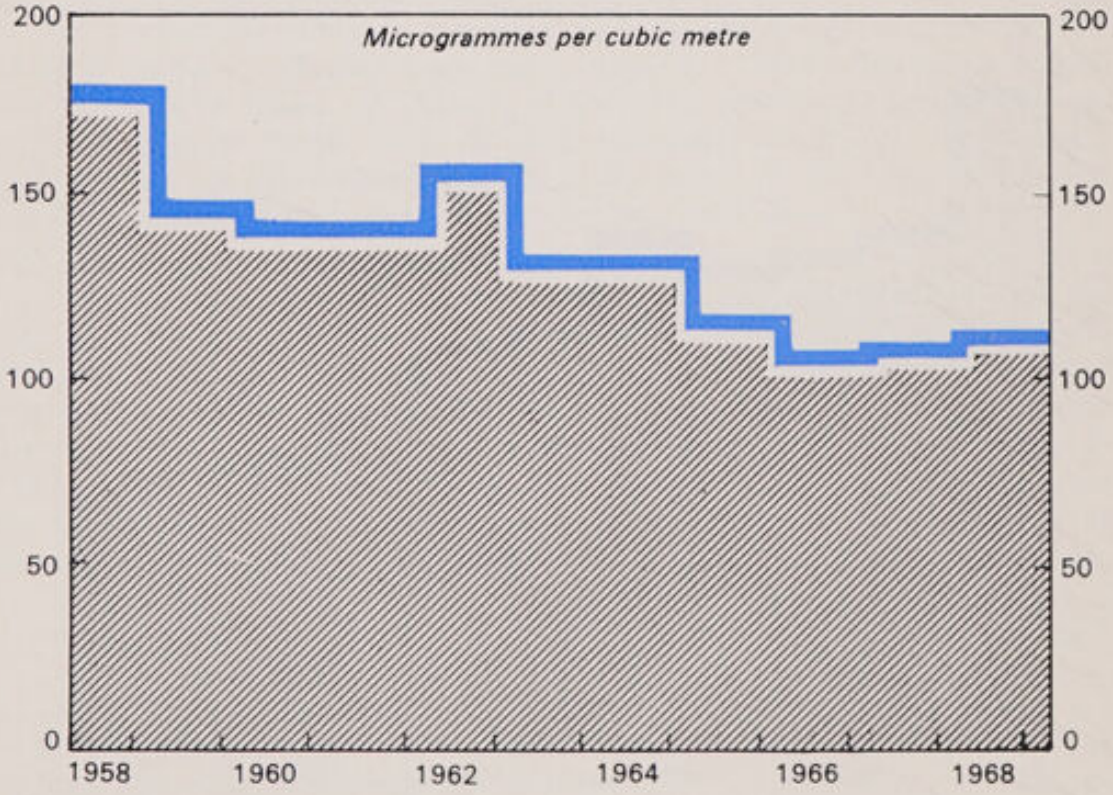


FIGURE 5

Trend of winter sunshine (December to February) at London Weather Centre and Kew Observatory

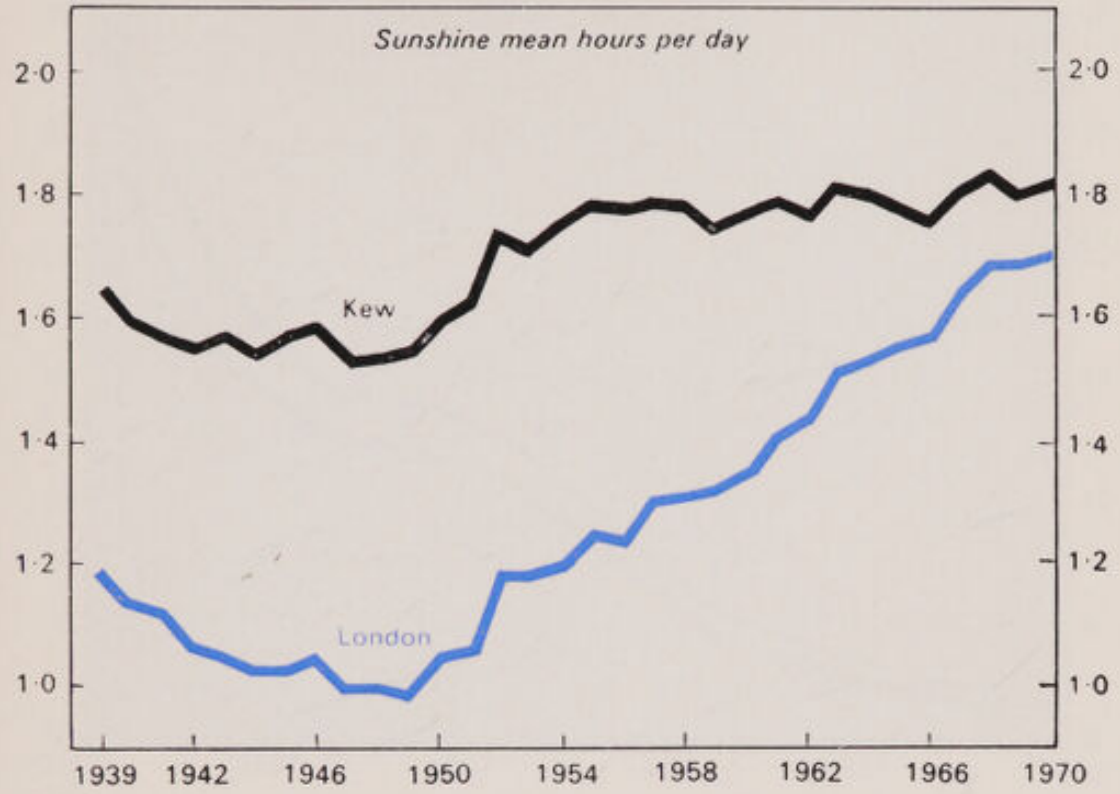


FIGURE 6

Forecast of total number of motor vehicles in Great Britain

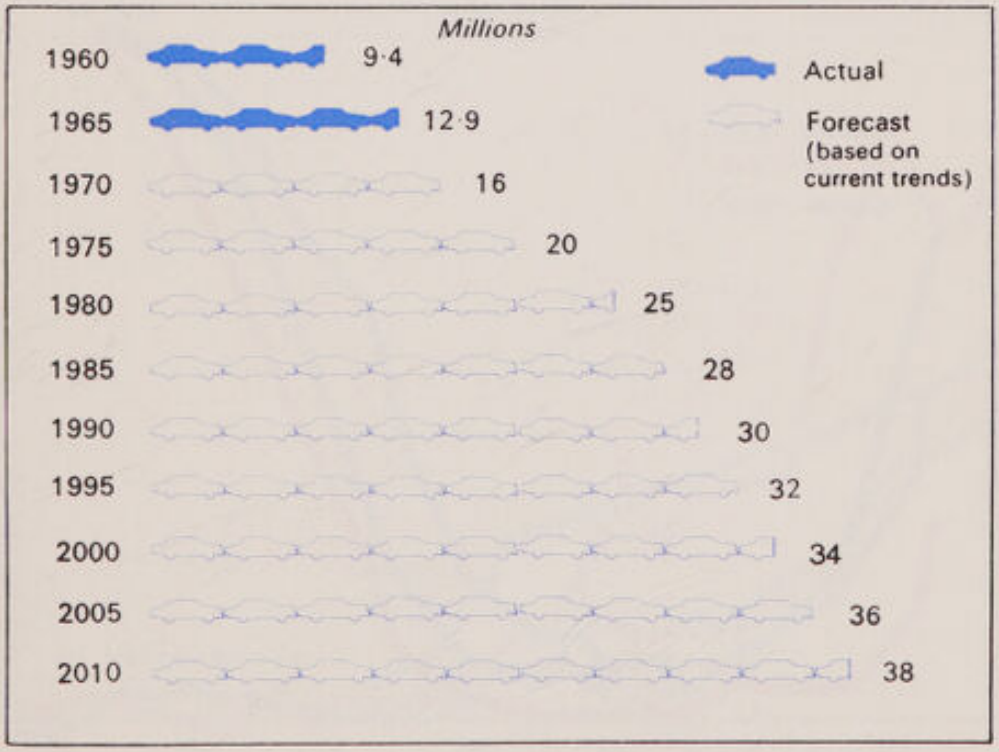


FIGURE 7

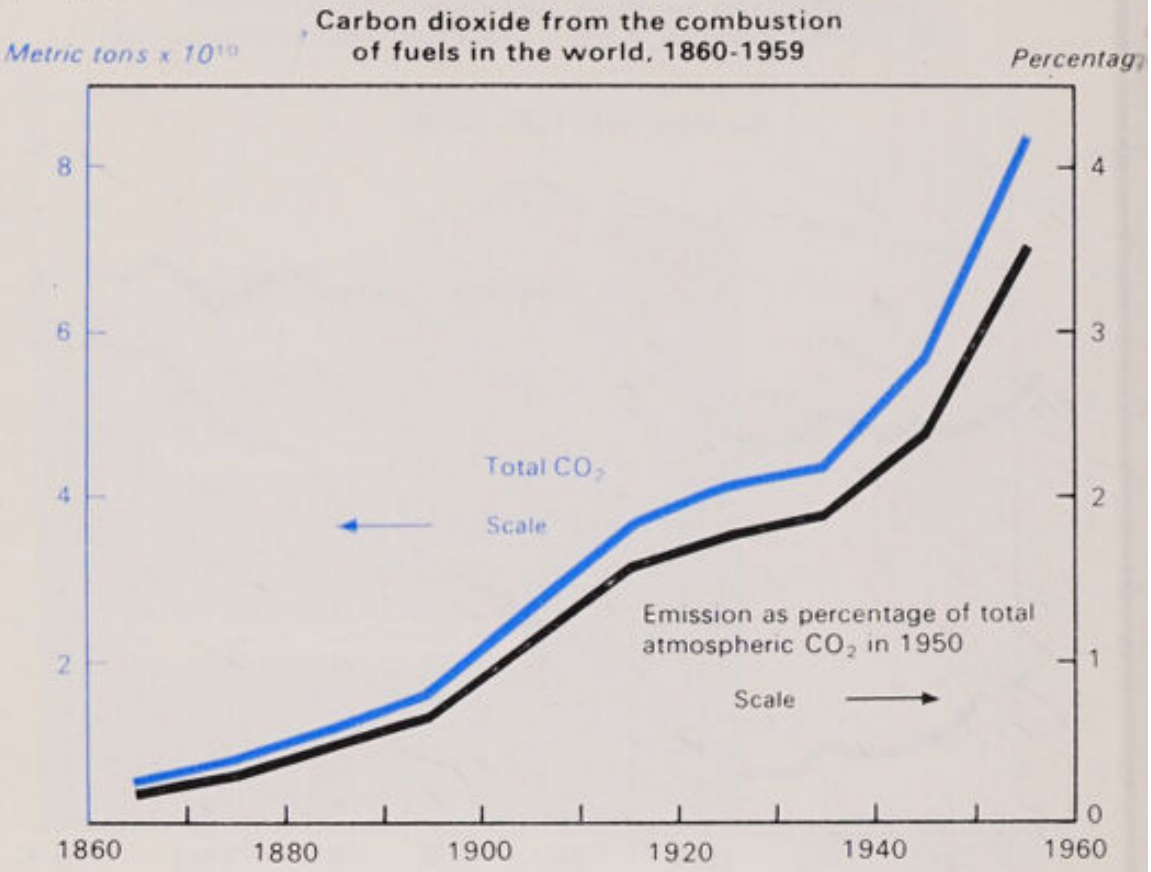


FIGURE 8

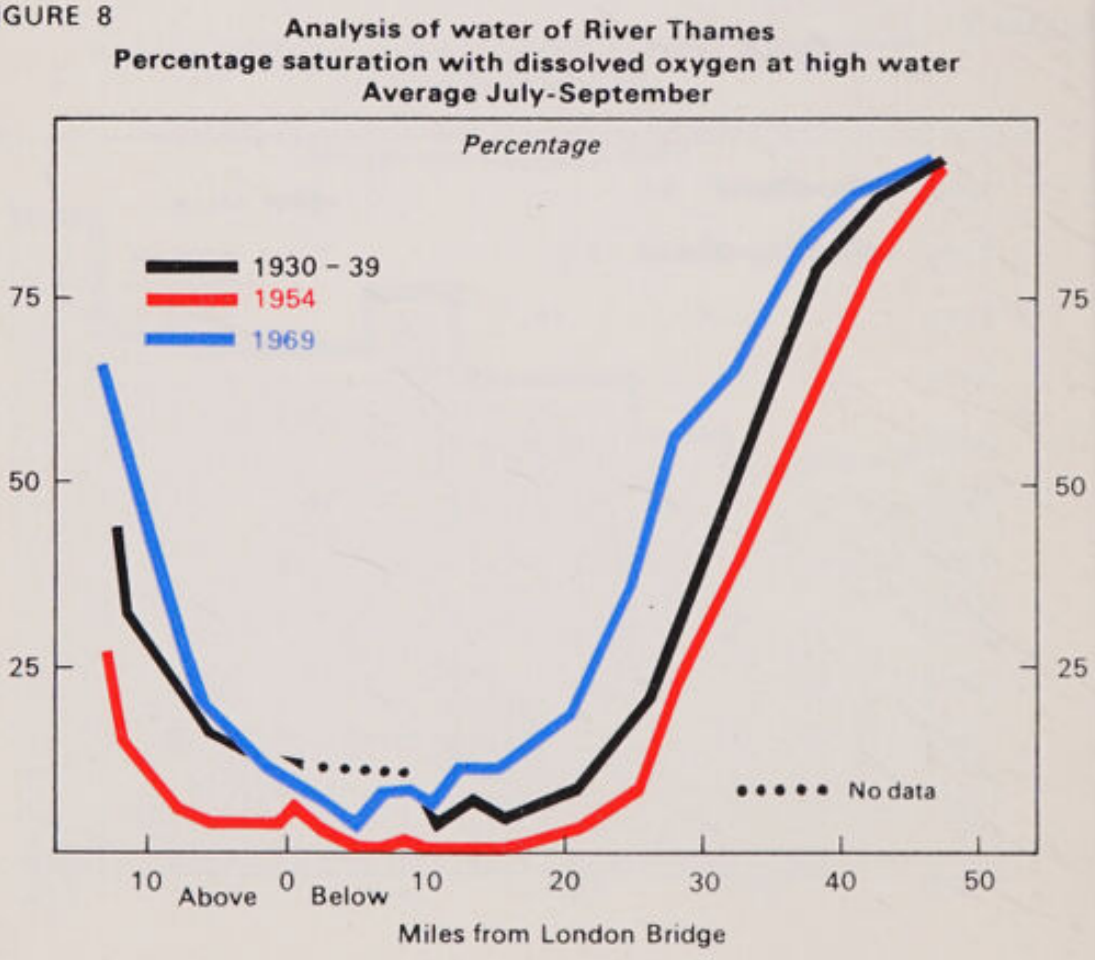


FIGURE 9

Total water consumption 1960-1969 with estimated requirements to year 2000
England and Wales

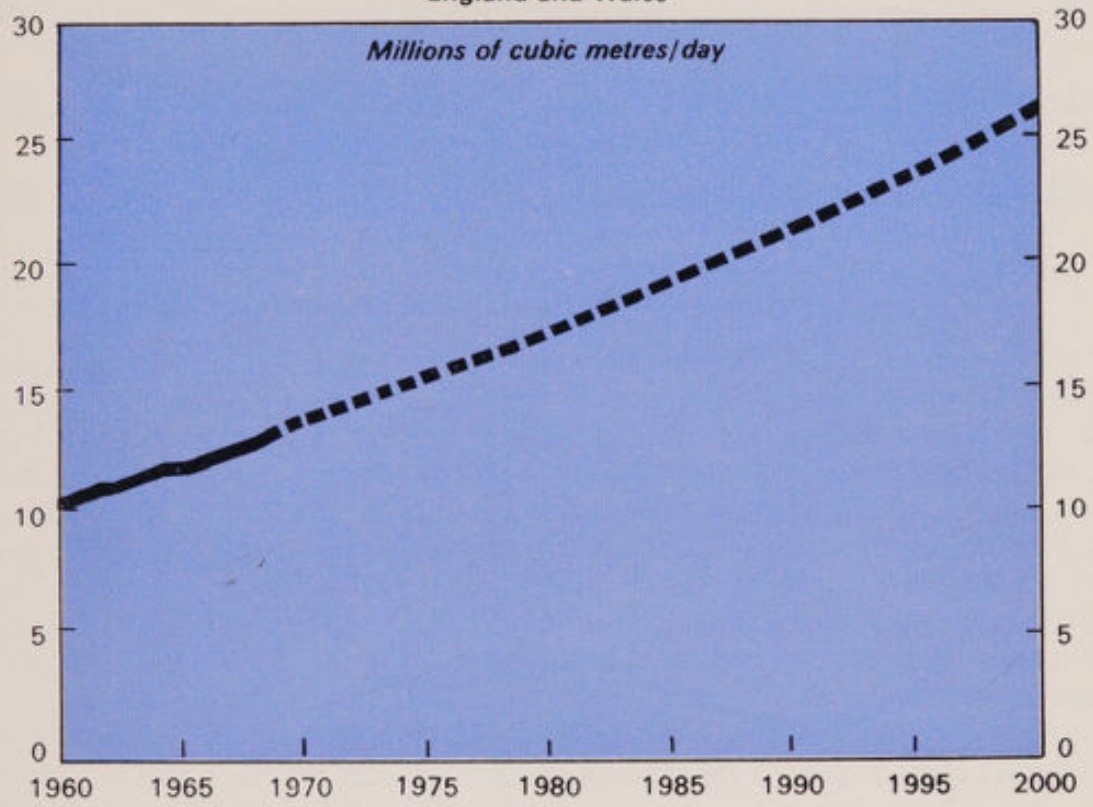


FIGURE 10

Comparison of phosphate content of two rivers with annual consumption of detergents

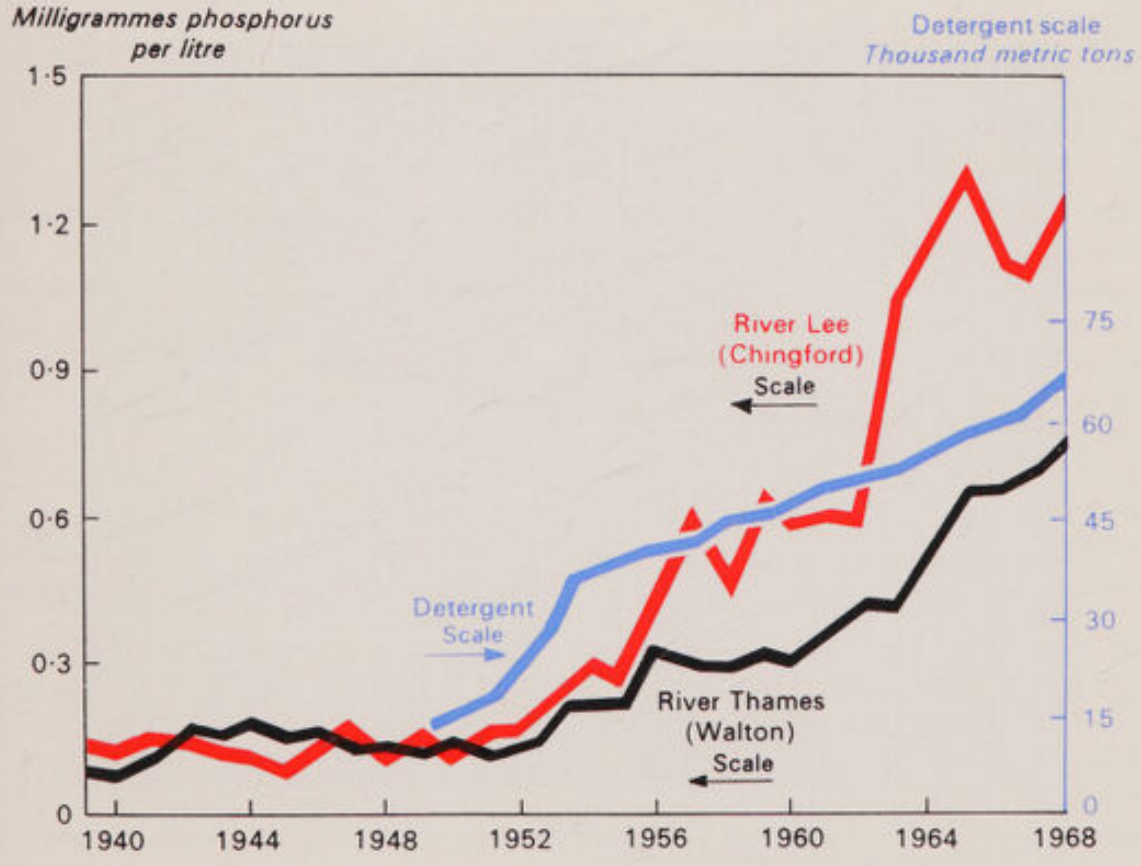
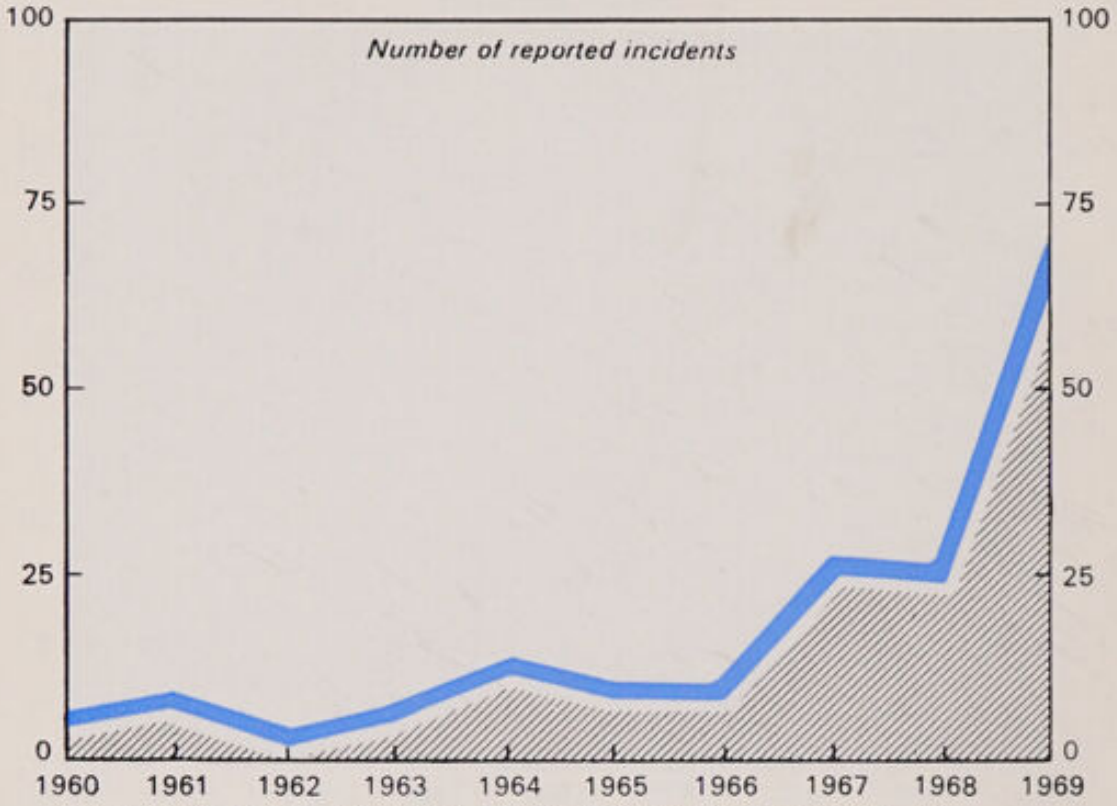


FIGURE 11

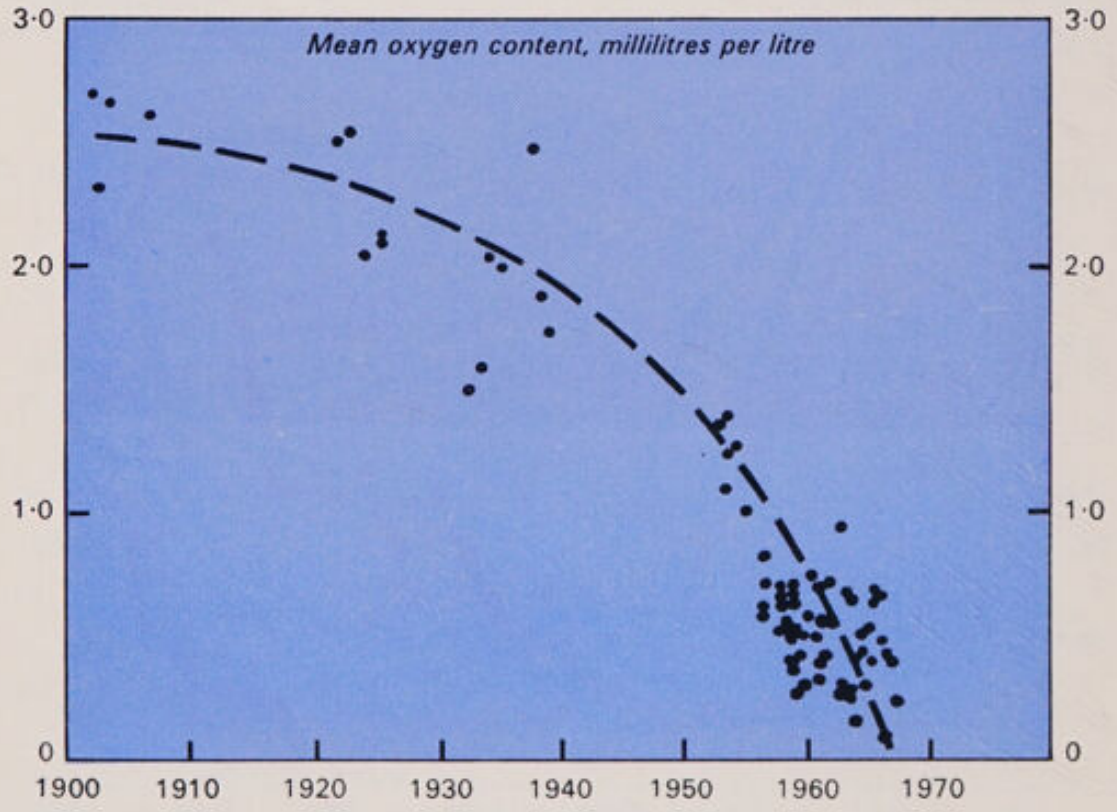
Oil pollution of the River Lee



Figures are for incidents reported to the Lee Conservancy Catchment Board

FIGURE 12

Reduction in oxygen content in deep water, Landsort Deep, Baltic Sea



Points indicate individual observations

Until the results of the current survey of conditions in England and Wales (now nearing completion) are published it is not possible to say reliably whether rivers are improving in quality. But three facts are indisputable:

(*a*) there are still some thousands of miles of polluted rivers in Britain, many of them needed as a source of potable water;

(*b*) future needs for water are such that it is essential to improve the quality of some rivers; and

(*c*) vigorous policies to improve rivers produce dramatic results.

This last point is well illustrated by the improvement of the Thames Estuary over the last decade. One of the criteria for unpolluted water is that it should carry sufficient dissolved oxygen to support fish. The oxygen content of the Thames for some 10 miles above and 30 miles below London Bridge had been diminishing for decades, and the consequences were beginning to be very serious. In 1949 the Water Pollution Research Laboratory began an investigation into the causes of the deterioration. When these were diagnosed, the former London County Council launched a programme to improve the quality of the water (Figure 8)(13). The success of this programme has been shown by the return of many kinds of fish. In 1957–58 a survey showed no fish between Richmond (15 miles above London Bridge) and Gravesend (25 miles below). By 1967–68 some 42 species were present and migratory forms were able once again to move through the polluted zone(14).

56. The amount of water supplied daily by statutory water undertakings to homes and industry in England and Wales has risen from 2,200 million gallons (10 million cubic metres) in 1960 to about 2,900 million gallons (13 million cubic metres) in 1969, and the demand is expected to double over the next 30 years (Figure 9)(15). No doubt there will be a comparable increase in the water requirements of other parts of the United Kingdom. Most of this water is returned each day to the river systems in sewage and industrial effluent and the volume of this waste is also expected to double by the year 2000. About one-third of public water supplies at present comes from rivers which also serve as channels for the disposal of effluent; this proportion is likely to increase in the future. The usefulness of rivers for water supply naturally depends on their purity; this in turn depends on their volume and rate of flow, and the amount of pollutant that is discharged into them. The capacity of a river to dilute pollutants and render them harmless is fixed by its size, so that if in future a river is to receive twice as much effluent as it does now, and yet not become less pure, the effluent will have to be twice as clean as present standards require. If the river is to be made still cleaner—as will certainly be necessary in many cases if it is to be used for supply purposes—an even higher standard of effluent purity must be achieved, and this will require more thorough treatment at higher cost.

57. Sewage treatment aims to remove bacteria and toxic substances, and to break down organic matter before the effluent is discharged, so reducing the "oxygen demand". But the kinds of treatment commonly used do not remove the nitrate and phosphate liberated in the breakdown process. In rural areas the bulk of nitrate in rivers comes from the land, but about half the total phosphate in our lowland rivers comes from household detergents. Both nitrate and

phosphate levels in many British lakes and rivers have risen over the past 20 years (Figure 10)([16]). In the U.S.A. and some other countries similar increases have been associated with the so-called "eutrophication" of lakes and rivers; a process in which the fertilization of the waters by nitrate and phosphate, both of which are essential to plant growth, leads to outbursts or "blooms" of microscopic plants which can block filters and render water unfit to drink. In Britain such blooms have been, and remain, rare, possibly because our rivers have short courses and because we have few large lakes in the lowlands. But there have been troublesome growths of water weed and a few interruptions to the use of reservoirs. Eutrophication may become more frequent as more reservoirs are built in agricultural areas and if lowland rivers and estuarine barrages are used. The Water Pollution Research Laboratory and the Natural Environment Research Council are supporting research on plant blooms, and the effect of detergents is being kept under review by a Standing Technical Committee on Synthetic Detergents. For another reason the rising trends in nitrate concentration are being watched by public authorities. Above a certain threshold (set at 100 parts per million by the World Health Organisation) nitrate can be dangerous to bottle-fed infants([17]). This threshold is not at present being approached in any major river system in Britain, though it has been exceeded in a very small number of wells and boreholes. In such cases the problem is normally dealt with by dilution but in at least one area special water is provided for babies.

58. Industrial effluents present a different problem. Although discharges are generally carefully controlled by River Authorities so that gross pollution with toxic wastes does not occur, some rivers carry substantial amounts of metal salts and this may hinder the use of the water for consumption. Pollution by oil has increased in many rivers over the past decade, especially in heavily populated districts. Figure 11 shows what has happened in one such example([18]). The likely sources of this pollution are accidental spillages in places having oil heating, the discarding into sewers or drains of used lubricating oil from motor vehicles, and waste industrial oils. Pollution by hard detergents is far less of a problem now than it was a decade ago, because modern household detergents are broken down by bacteria (that is, they are "biodegradable"). However, detergents used in textile factories are less easy to make biodegradable, and effluents containing these detergents are liable to cause foaming in rivers. But here, too, progress toward biodegradable detergents is being made, so that the end of this problem should soon be in sight, even though total detergent consumption in Britain continues to rise (Figure 10)([19]). In some countries, hot water discharges from the cooling systems of power stations into rivers are causing concern. This is not a serious environmental problem in Britain because most power stations use towers to cool the effluent and because our large nuclear-fuelled generation plants are mostly sited on the coast. Finally, there remains the problem that new synthetic substances, whose biological effects cannot always be predicted, may be discharged in small quantities in industrial effluents. One example is the discharge of polychlorinated biphenyls (PCBs), which have been found to be persistent and to accumulate in birds and animals.

Pollution of the sea

59. Unless they are broken down by living organisms or deposited in insoluble form in the mud at the bottom of lakes and rivers, the pollutants discharged

into fresh waters ultimately find their way to the sea. So do many of the pollutants released into the air, which may eventually dissolve in rain or in the sea itself. In addition, many towns discharge sewage and industrial waste directly into estuaries and inshore seas and it has become established practice for certain peculiarly noxious forms of waste to be dumped at sea outside territorial limits. In the past, many people seem to have thought that once a pollutant had been dispersed in the sea, the problems associated with it had been solved.

60. The sea's capacity to degrade and dilute waste is enormous, but it is not infinite. Already some isolated and stagnant basins within largely land-locked seas are showing major changes due to pollution: parts of Oslo fjord are examples. Other examples can be found in the Baltic, although the decrease there in oxygen concentration may also result from certain other causes because changes in the salinity of the water have taken place at the same time. Figure 12 shows how the amount of oxygen in one part of the Baltic has declined since the beginning of the century(20). An additional complication is the way in which certain kinds of marine life actively concentrate substances, such as metals and organochlorine pesticide residues, with the result that their bodies may contain quantities a hundred or even a thousand times greater than in the sea itself. Accumulations of mercury in fish have become more widespread. Indeed, in some areas around Scandinavia they have reached the point at which fisheries have had to be closed down.

61. The seas around Britain lack such isolated stagnant basins and there is no evidence that pollution is causing such serious changes there at present. But the amounts of waste shed into these seas are considerable. Every day about 5 million cubic metres of domestic sewage, 3 million cubic metres of industrial waste, and 7 million cubic metres of cooling water from power stations are discharged along the east and south coasts of England alone(21). A further large volume of treated sewage effluent enters the sea in the inflowing rivers. In addition, about 4 million tons of colliery waste and 1.5 million tons of china clay waste are dumped each year off the north-east and south-west coasts respectively. Much smaller amounts of industrial waste and sewage sludge are got rid of in the open sea, outside territorial waters, but some of the material thus disposed of is highly toxic(8). The volumes of all these kinds of waste entering the sea are increasing, and are likely to go on doing so, unless steps are taken to halt this trend.

62. In recent years the resources of the seabeds have been increasingly open to exploitation. In some cases, for example, from oil fields in shallow waters, severe accidental pollution has already occurred from which there may be irreversible effects. Little is known of the possible effects of dredging or drilling of the deep sea floor, which technology is making increasingly accessible(22).

63. Britain does not dump highly radioactive waste in the sea. Some weak radioactive waste is, however, disposed of at sea in special metal and concrete containers in deep water away from fishing grounds and cable routes. These disposals are in accord with international practices to which the United Kingdom is a party.

64. The sea is often polluted accidentally. Each year about 50,000 tons of oil (about half that shed in the "Torrey Canyon" disaster) contaminate our beaches

and inshore seas, killing seabirds and shell fish, damaging amenity, spoiling public enjoyment, and presenting local authorities with an expensive bill(23). Once this pollution has taken place, nothing can be done except clean it up, and both the methods and the organisation for doing this are continually being improved. But it is obviously better to stop the oil entering the sea at all, and for this reason Governments, the petroleum industry and shipping operators have been in close touch, especially through the Inter-governmental Maritime Consultative Organisation which has drafted International Conventions now accepted by Britain and many other countries. Most tanker operators have adopted the "load on top" system, which retains on board the oil washed from tanks when they are cleaned. Throughout the world, this system is estimated to have saved some 3 million tons a year of oil which would otherwise have been discharged into the sea. Somewhat over half a million tons of oil, however, are still believed to enter the sea each year from tankers which do not operate this system. Spillage and bilge-water from ships other than tankers add perhaps another three-quarters of a million tons a year. A wider measure of co-operation in the international conventions could reduce oil pollution caused during the normal operation of ships, but with more and larger tankers entering service, the danger of a massive accident still remains, as was demonstrated by the collision involving the "Pacific Glory" in October 1970.

65. So far, there is no evidence of any widespread damage to marine life or fisheries in British waters. But there is evidence of local effects on the growth of marine plants in polluted areas along the Durham coast and in Liverpool Bay, and damage has been done to fisheries in many major estuaries, including those of the Clyde, Forth, Tyne, Tees and Thames. Residues of pesticides like DDT, and of PCBs (paragraph 58), are widely distributed in marine life and concentrated in the oily livers of some fish and the body-fat of seals and seabirds. Levels of organochlorine pesticides and, more recently, of PCBs have been monitored in marine life, birds and seals and an increasing amount of research is being done on the effects of pollution on the life of our shallow seas, where a substantial proportion of our productive fisheries is located. This research is helping to determine how serious the problems are, and whether it may be necessary to impose new controls on the substances used in farms, industries and homes.

66. The River Authorities have jurisdiction over what goes into the sea through our rivers; it would be comparatively simple to extend some form of statutory control over all discharges to the sea from coastal pipelines and outfalls, as has been recommended by the Working Party on Sewage Disposal(12). We have a voluntary scheme to regulate the dumping of waste by ships working from our ports; the conversion of this to a statutory system would be practicable. But many problems of pollution affecting the high seas must be dealt with internationally. Britain has participated in a study of the pollution of the North Sea organised by the International Council for the Exploration of the Sea(21), and is taking part in discussions under the Inter-governmental Maritime Consultative Organisation, the N.A.T.O. Committee on the Challenges of Modern Society and other international organisations. These international discussions are multiplying as the magnitude of the potential problem is realised by more and more nations. The trend is undoubtedly towards an increasingly close

control over all forms of waste disposal to the sea: for example, the United States Council on Environmental Quality has proposed stringent regulation of dumping of waste at sea by the United States(24). The problem is too complex to be resolved by "blanket" international controls which do not take account of local conditions, and it is likely that localised international agreements would be much more effective.

Radioactive waste disposal

67. The hazards of radioactive waste are so serious that very great care is taken over its disposal. Highly active solid waste, which comes from the stripping of irradiated fuel elements, is stored in massive concrete silos. Less highly active solid waste is burnt, or buried in two sites in northern England, or is dumped at sea in such a way that it does not escape. Liquid wastes are stored or, if their radioactivity is very low, they can be discharged without risk. All this disposal is, of course, strictly according to requirements laid upon the U.K. Atomic Energy Authority. The Ministry of Agriculture, Fisheries and Food conducts limited monitoring of coastal waters for radioactivity. These checks in 1968 show that in many cases there was no radiation exposure at all from radioactive wastes, and where there was measurable radiation it was within internationally accepted limits.

68. The increasing use of atomic energy for power will require arrangements for waste disposal on a far larger scale than at present. These arrangements will be the concern not only of Britain but of all nations generating power from atomic energy. Accordingly in Chapter IV we include the disposal of radioactive waste among the problems of pollution which need enquiry, although there is no cause for disquiet about present practices.

Noise

69. Man-made noise arises mainly from two sources: industry and transport; though perhaps we should add a third source: the sound level of some music transmitted through amplifiers. Industrial noise, notably from mechanical saws and pneumatic drills, can be a nuisance to the public; and noise inside factories can become a health-hazard, causing deafness. Information collected by the Association of Public Health Inspectors indicates that the number of complaints of noise nuisance received by local authorities is increasing at the rate of about 10 per cent each year.

70. The main menace of noise comes, however, from transport. It is estimated that between about 20 and 45 per cent of the urban population live in roads with noise-levels from traffic likely to be judged undesirable for residential areas; if the number of vehicles increases according to predictions, and if their noise-level is not reduced, the percentage of the urban population whose homes will be exposed to undesirable traffic noise by 1980 will be between one-third and two-thirds(25). Noise from motor cycles and other road vehicles is already subject to legal limitation, but some of these regulations do not seem to be frequently enforced. Regulations introduced in April 1970, if they are firmly applied, should prevent a worsening of traffic noise. But the present regulations will not do much to satisfy the public demand for less noise.

71. Noise from aircraft is causing even more public disquiet than noise from road transport. It is true that a great deal of work has been done to reduce the noise from jet engines and new types of engine are much quieter than their predecessors. This is reflected in the new scheme for aircraft noise certification, introduced under the Air Navigation (Noise Certification) Order, 1970, which will ensure that, weight for weight, new subsonic jet aircraft using United Kingdom airports will be about half as noisy as those now flying. But if the volume of air transport continues to expand at a rate of 15 per cent per annum, the nuisance from aircraft will not easily be remedied, particularly if supersonic is added to subsonic flight.

CHAPTER IV

CHOICE OF PRIORITIES

Introduction

72. In paragraph 31 of Chapter III we outline two different kinds of priorities necessary for working out a comprehensive policy for controlling pollution: priorities for action and priorities for enquiry. Among priorities for action are:

(*a*) the need to provide, for example by improved sewage treatment, for increases in demand for water for various uses;

(*b*) the need to control the disposal of solid and semi-solid toxic wastes on land; and

(*c*) the need to reduce noise from traffic, aircraft and some industrial machinery.

These are all matters on which the Government have already received, or will shortly receive, authoritative advice. Another high priority is the need to control the dumping of noxious materials at sea. This is part of a wider issue which we ourselves will investigate, but there are some practices on which immediate action seems appropriate and on which we hope that the Government will feel able to proceed.

73. As for priorities for enquiry, we summarise first in paragraphs 74 to 81 those problems which seem to us to be receiving attention from other bodies and which, therefore, despite their importance, do not at present call for any initiative or special study by the Commission. We are concerned, however, that the attention which these problems are receiving should as promptly as possible be translated into effective decisions.

Problems already receiving attention from other bodies

74. **Air pollution.** Present scientific and technical knowledge is adequate to reduce smoke, grit and dust, and sulphur dioxide. Emissions from motor vehicles are receiving concentrated attention. The first of a series of reports from the Warren Spring Laboratory on the National Survey of Air Pollution, which began in 1961, is expected to be published early in 1971. The report of a survey of research was published in the 1970/71 Year Book of the National Society for Clean Air. These reports will provide a basis for further development of the clean air policy, including the control of smoke and sulphur dioxide, identification of areas where control is inadequate, and maintenance of the essential programme of monitoring. More research is needed in order to adapt known techniques of pollution control to particular industries and processes. This need has already been stressed by the Alkali Inspectorate([26]) and we strongly endorse its recommendations.

75. There is uncertainty about the long-term effects of exposure to low concentrations of the gases emitted by motor vehicles. The Air Pollution Unit of the Medical Research Council is working on this problem.

76. **Disposal of solid wastes on land.** The disposal of refuse is being studied by the Warren Spring Laboratory and the report of the Working Party on Refuse Disposal is expected to be published in the Spring of 1971. The recently published report of the Technical Committee on the Disposal of Solid Toxic Wastes discloses practices which need urgent attention and its advice is clearly sufficient to guide Government action for the immediate future.

77. **Pollution and agriculture.** An Advisory Committee on Pesticides and Other Toxic Chemicals keeps under review the use of pesticides in agriculture and industry. Scientists of the Nature Conservancy and of the Ministry of Agriculture, Fisheries and Food and in industry are studying the effects of pesticides on wild life, and on the levels of accumulation of residues in birds and animals. One of the points at issue is whether the use of organochlorine pesticides (paragraph 50) should be restricted by voluntary agreement or by mandatory control. We understand that, following the Advisory Committee's review of the subject published late in 1969, good progress has been made by the Government, with full support from industry, to restrict the use of these substances. Nevertheless in an earlier report, published in 1967, the Advisory Committee did conclude "that in matters of such importance, the Government should have full power of decision and not have to rely on the voluntary co-operation of commercial organisations however responsible they may be"(27). The reasons for this conclusion were that the voluntary system, although working "remarkably well", could not be comprehensive, covering all distributors; also that it does not take account of what the Committee calls "backlog" ingredients which have been on the market for some time and may escape the net of voluntary control. We strongly support this view. Unfortunately, while makers and distributors of pesticides are keen to maintain the good working relationship they already have with Government Departments over this problem, they are not unanimous about whether or not they would prefer a mandatory system of control in place of the present voluntary scheme. We therefore include this problem among the gaps on which further action is needed (paragraphs 89–90).

78. A Farm Wastes Disposal Committee under the Ministry of Agriculture, Fisheries and Food continuously reviews the disposal of farm wastes and offers advice to farmers and we understand that additional resources have been provided for research into this matter. The problems of wastes from intensive farming and those associated with the use of artificial fertilisers were also among the points considered by the Agricultural Advisory Council, as part of its study of the effects of modern agricultural practice on the structure and fertility of the soil. The Council's report was published in January 1971.

79. **Fresh water pollution.** The steady increase in the demand for water, quite apart from recreational needs, makes a clean rivers programme essential. Recycling of water, that is, its use, purification and re-use, is recognised as a major national challenge. The problem is already receiving intensive study. The analysis of the first survey of river conditions in England and Wales since 1958 is expected to be published in 1971. The Central Advisory Water Committee is expected to report in mid-1971 on the organisation of responsibilities for water conservation, water supply and sewage disposal. The Water Resources Board is conducting, in co-operation with the Trent River Authority and other bodies, a major study of the supply and use of water in that area. A Working

Party on Sewage Disposal has already published its report: "Taken for Granted"(12). The results of all these investigations should make a major contribution to the formulation of a national policy for rivers.

80. **Pollution of the sea.** Oil pollution of the sea is now the subject of a number of international conventions within the Inter-governmental Maritime Consultative Organisation (I.M.C.O.) in which the British Government play a leading part. In particular, the 1969 amendments of the 1954 International Convention for the Prevention of Pollution of the Sea by Oil, which tightened the earlier controls, will be enforced for the United Kingdom by the Oil in Navigable Waters Bill. Other I.M.C.O. Conventions remain to be ratified by legislation; international talks continue about these and other matters relating to sea pollution, including the transport of hazardous cargoes. This does leave, however, other urgent problems about discharges into the sea of sewage and industrial waste; we refer to these later in this chapter (paragraph 86). The possible effects arising from dredging or drilling of the deep sea floor to which we refer in Chapter III, paragraph 62, point to the need for further enquiry and research before some, and perhaps all, forms of this exploitation are permitted; otherwise the consequent risk of marine pollution may reach significant proportions. This in turn points to the urgent need to conclude international legislation to define the present limits of national jurisdiction in more precise terms than those of the Continental Shelf Convention of 1958 and to provide an effective regime beyond the limits of that Convention.

81. **Noise.** A debate last year in the House of Commons (Hansard: 21 July, 1970, cols. 286–374 and 22 July, 1970, cols. 375–396) showed that noise is the form of pollution causing greatest concern to many members of the public, and it was suggested that the Commission should give it urgent attention. There is, however, a statutory Noise Advisory Council under the chairmanship of the Secretary of State for the Environment, although he has no executive responsibility for the control of aircraft noise. The Council has begun its task of advising the Government on the abatement of all forms of noise and has published a review of its first eight months' work. We share the increasing public concern about noise; it could soon become an intolerable by-product of modern society. Therefore we shall keep in close and constant touch with the Noise Advisory Council and we shall if necessary keep this matter high on our agenda.

Problems to which further attention needs to be given

82. **Economic considerations.** Our survey of the activities of Government, industry and voluntary bodies in the control of pollution discloses several issues which need further enquiry. The first and most difficult of these is how to balance the considerations which determine the levels of public and private expenditure on pollution control. Some forms of pollution bear more heavily on society than others; some forms are cheaper than others to control; and the public are more willing to pay for some forms of pollution control than for others. There are also short and long-term considerations: in the short-term the incidence of pollution control on individual industries or categories of labour may be heavy; but, as the Prime Minister has clearly pointed out(*), what may appear to be the cheapest policy in the short-term may prove in the long-term to have been a false economy.

*Prime Minister's speech at the Countryside in 1970 Third Conference, 28 October 1970.

83. While the broad outlines of a general policy for protecting the environment are not difficult to discern, the economic information needed to make a proper assessment of the considerations referred to in the preceding paragraph, and in Chapter II, seems to us to be seriously deficient. This is in striking contrast with the position regarding the scientific and technical data where, as our survey has shown, a considerable amount of information is already available and various bodies are trying to fill in the main gaps. The scientific and technical information is invaluable, and in many cases may be adequate for reaching satisfactory decisions, but much of it could be wasted if it were not supported by some economic indication of priorities and of the best means of dealing with specific kinds of pollution.

84. So, where possible, we need an economic framework to aid decision-making about pollution, which would match the scientific and technical framework we already have. This economic framework should include estimates of the way in which the costs of pollution, including disamenity costs, vary with levels of pollution; the extent to which different elements contribute to the costs; how variations in production and consumption affect the costs; and what it would cost to abate pollution in different ways and by different amounts. There may well be cases where most of the costs and benefits of abatement can be assessed in terms of money. Many of the estimates are likely to be speculative, but this is no reason for not making a start. There are other cases where most of the costs and benefits cannot be given a monetary value. In these cases decisions about pollution abatement must not await the results of a full economic calculation: they will have to be based largely on subjective judgments anyway. Even so, these subjective judgments should be supported by as much quantitative information as possible, just as decisions about health and education are supported by extensive statistical data. Further, even if decisions to abate pollution are not based on rigorous economic criteria, it is still desirable to find the most economic way of achieving the abatement.

85. **Qualifications and training.** A great many people are employed to control air and water pollution: by central Government and local authorities, by river and drainage authorities, and by industry. Some of these staffs are highly trained and have easy access to the best scientific and technical work in their fields. Others, however, particularly those working for some local authorities, do not have either training or qualifications commensurate with their responsibilities; they are obliged to use old-fashioned techniques for sampling and monitoring because they do not have the resources for up-to-date equipment; often they work in isolation and have no easy access to professional advice. The public have only recently come to appreciate the importance of the services these men and women perform. The inducements to enter these services are not attractive and the opportunities for acquiring professional expertise in some cases appear to be inadequate. Modern industry gives rise to novel and sometimes highly technical problems of pollution control. While many of these can be solved within industry, there remain some which will fall upon local authorities and River Authorities. We doubt whether some staff engaged in these services, especially those attached to small local authorities, have the scientific and technological training, or the contact with experts, which would enable them to make informed decisions on unforeseen problems. All this leads us to think that a

review of the qualifications and training, and access to scientific and technological information, of those who control pollution might lead to measures which would encourage these services and improve them. We note that the report of the Working Party on Sewage Disposal comes to a similar conclusion.

86. **Estuaries and the seas.** The report of the Working Party on Sewage Disposal considers fully the discharge of sewage into estuaries and the sea, and makes some useful recommendations. But tidal waters, estuaries and the seas near our coasts are also polluted in other ways and there is not the same sense of responsibility, nor is there the same legislative provision, to protect these waters as there are to protect rivers. The recent disclosures about the presence of mercury in imported tuna fish is an example of the potential dangers. Pollution of the sea is a matter for international enquiry. In shallow waters, like the North Sea, urgent decisions may have to be made about the dumping of noxious wastes. The problems of sea pollution are being studied by scientists in several countries. But we think there is a need, without waiting for the results of these studies, for a comprehensive enquiry into the extent of discharges and dumping of wastes into tidal waters, estuaries and the seas round our coasts, and into the kinds of control which should be exercised.

87. **Monitoring.** It is impossible to say how rapidly and in what forms the environment is improving or deteriorating unless the quality of water and air is monitored and unless statistics are collected about the disposal of waste on land and the amount of dereliction in urban areas; nor can standards be set without the data from monitoring and other measurements. But monitoring and the compilation of statistics can be costly and wasteful of manpower; it is therefore essential to collect data in forms which can be effectively used. This calls for uniformity of techniques and units of measurement, which should preferably be agreed internationally, and careful decisions about the amount of monitoring to be done. In some cases the criteria for fixing standards—and therefore the things to be monitored—need to be determined. A study of monitoring and the collection of statistics would enable us to suggest just what monitoring is needed and how it should be done, in order both to help decision-making and to keep the public informed about what is happening in the environment.

88. One type of monitoring deserves special mention, namely, the measurement of levels of certain pollutants in animals and plants. There are grounds for extending the use of this "biological" monitoring, because it is a highly sensitive means of surveillance and can lead to the identification of pollutants whose effects were hitherto unsuspected. Since many toxic substances have delayed or cumulative effects, the first sign of harmful consequences is likely to appear in the unaccountable ill-health or mortality of plants or animals, or even people. Substances in this category, which are or might be discharged into the environment, include the heavy metals, pesticide residues and other biologically active chemicals. Even when they are present in soil, air or water in undetectably small amounts, they can be selectively concentrated by living cells. Consequently, the most practicable way of detecting them is by making routine surveys of those species of animals and plants which appear likely to serve best as indicators.

89. **Pesticides.** We point out (paragraph 77) that makers and distributors of pesticides disagree as to whether or not they prefer voluntary or mandatory

control of all such products. It is probably for this reason that the Government have not yet announced a decision on this matter. We ourselves have not taken evidence on it, but reports already published convince us that mandatory control is desirable and will in the end be inevitable. We believe that there is already enough evidence to enable the Government to reach a decision and to introduce legislation at an early date.

90. Quite apart from the question of legislation we consider it most important that there should be a continuing appraisal of all pesticide use in the U.K., with emphasis on long-term research on the ecological effects of all these materials on the minimum effective doses of those persistent pesticides which have to be used, and on the possible hazards of substances intended to replace existing products. Phased replacement of the more persistent pesticides by less persistent pesticides is a matter of urgency, and it should take place as rapidly as the development of satisfactory alternatives permit. We propose to review progress on this matter by the end of 1972.

91. **Radioactive waste.** Finally, whilst the present control of disposal of radioactive waste is satisfactory, within existing limits, we are moving into an era when more and more power will come from nuclear power stations. This problem, though not imminent, is one which will have to be solved at international level, and it needs foresight now.

92. These are only six examples of broad topics within our terms of reference to which we think more attention should be given. There are many other more limited topics of importance. Derelict land, for instance, can be cleaned up by local authorities with the aid of grants from central Government, supplemented in certain instances by voluntary efforts, but much derelict land remains. Careless dumping not only of toxic materials but also of other materials is a nuisance to river and sewage authorities. The condition of transport by road, rail and water of potential pollutants needs further investigation. And, in the field of technological development, there is a need to enquire whether some processes could not now be made more efficient by applying modern techniques of chemical and process engineering.

The Commission's programme for 1971-72

93. Our terms of reference authorise us to enquire into any matters on which we think advice is needed. In paragraphs 82 to 91 we outline several matters which we think merit further enquiry. We have chosen for study in the first instance one matter which we think is more urgent than others, namely, an enquiry into the pollution of tidal waters, estuaries and the seas round our coasts. We refer to this problem in Chapter III, paragraphs 61 to 66 and paragraph 86 of this chapter.

94. In addition to a full enquiry on this problem we shall keep under review action on the improvement of Britain's rivers. The Secretary of State for the Environment has already received from us, at his request, our comments on the report of the Working Party on Sewage Disposal. In our reply to the Secretary of State we said that we supported the majority of recommendations in this excellent report. Three issues arising from the report seem to us to be particularly important. They are as follows:

(*a*) In each river region one and the same authority should be responsible for the whole water cycle, controlling what is put into the river as well as what is taken out of it. At present River Authorities and sewage authorities are independent of one another. (We know that this issue is being considered by the Central Advisory Water Committee and we shall be invited by the Secretary of State to comment on the Committee's recommendations. But we nevertheless want to put on record this view, which we have already reached from our study of the Working Party's report and our enquiries when we visited the Trent River Authority and the Upper Tame Main Drainage Authority.)

(*b*) The qualifications and opportunities for training of those who are responsible for inspecting and controlling pollution, particularly those within local authorities concerned with sewage, should be improved.

(*c*) The techniques of up-to-date process and chemical engineering should be more extensively applied to the design and operation of sewerage and sewage plant. This would be assisted by improving the communications between: (i) the staff specifically concerned with sewerage and sewage, and (ii) the various bodies with expert knowledge in the general field of process and chemical engineering, namely, scientific, technological and professional institutes, design and erection contractors, equipment fabricators and the process industries.

The need for economic studies

95. We believe that there is a need for research on the economics of pollution. The economic issues raised in Chapter II, whether or not they are paramount, cannot be fully resolved without estimates of the costs and benefits of changes in the levels of different kinds of pollution. We emphasise above (paragraph 84) that one should not be insistent on the need for prior economic justification for decisions in the field of pollution abatement, but that there are obvious gaps in our information about the economic aspects of pollution. Accordingly, we think that a start should be made towards filling these gaps. We do not have in mind any large unit, or any permanent institution, but we do feel that economists could provide a firmer basis for many of the judgments about pollution which we shall need to make and many of the decisions which the Government will need to reach in the near future. This economic analysis should preferably be organised and carried out so as to fit in with the Commission's programme. We recommend that the Government should make suitable arrangements for this work to be undertaken.

CHAPTER V

GLOBAL EFFECTS OF ATMOSPHERIC POLLUTION

Introduction

96. Over the past century pollutants have been released into the air in mounting quantities. In recent years a good deal of attention has been given to the possibility that these pollutants may affect the climate of the earth as a whole. There have been alarming suggestions that substantial, irreversible and even catastrophic changes in world climate may occur within a few decades if man's activities continue unchecked. Although the most extreme of these suggestions are rejected by the majority of experts, the possibility that man's effect on the atmosphere has now become great enough to change the climate in a measurable way clearly demands critical scientific study.

97. We were asked, shortly after our appointment, to advise the Government on the adequacy of present research into these questions. In order to do this, we have naturally found it necessary to review existing information about the various pollutants and processes which have been suggested as potential modifiers of the climate. We have been helped in our appraisal by informal consultations with the Director General and staff of the Meteorological Office and the Director of the Warren Spring Laboratory. We wish to make it clear, however, that the statements and conclusions in this chapter are the sole responsibility of the Commission.

98. Human activities might affect world climate in several ways which interact with one another, for example:

(*a*) through increasing the amount of carbon dioxide in the atmosphere;

(*b*) through increasing the amount of dust, or the very fine dust technically called "aerosols", in the atmosphere, which would affect the penetration and absorption of the sun's radiation and some of which could serve as nuclei for the formation of water or ice droplets;

(*c*) through increasing the amount of water vapour in the lower stratosphere;

(*d*) through releasing substances not naturally present in the atmosphere, and so changing its normal chemical processes;

(*e*) through changing the rate of evaporation of water and the degree of reflection of radiation from the earth's surface; and

(*f*) through the direct warming of the atmosphere by the waste heat emitted by cities and industries.

In the following sections we examine these hypotheses in sequence and in each case consider where additional information is required.

Increases in carbon dioxide and their possible effect on climate

99. Carbon dioxide (CO_2) enters the atmosphere naturally as a waste product of animal and plant respiration, through the decomposition of living tissues, and through naturally-occurring fires. Man has added carbon dioxide chiefly by burning fossil fuels like coal and oil products. In the 1890s the carbon dioxide content of the atmosphere was around 290 parts per million (ppm): by 1960 it was 312 ppm and in 1969 320 ppm. Put another way, the carbon dioxide content of the atmosphere has risen by about 10 per cent since the 1890s, half of the rise taking place since 1945. The general trend is shown in Figure 7.

100. Since 1958 the levels of carbon dioxide in the atmosphere have been carefully measured in two places which are most unlikely to be affected by local pollution: the South Pole and the summit of Mauna Loa (13,000 feet) in Hawaii. The results from the two stations agree remarkably well, confirming a steady increase of about 0.7 ppm each year, with some slight variation according to the season.

101. The observed increase in carbon dioxide in the atmosphere is only about half of what would be expected if all that produced by burning fossil fuel remained in the air. Almost certainly, the "missing" carbon dioxide is being taken up by the oceans, and it has been calculated that the oceans contain about 60 times more dissolved carbon than the amount of carbon in the atmosphere. Much of this is in the form of magnesium and sodium carbonates and of carbonic acid itself. Exchange of this carbon between the atmosphere and the oceans is possible only through a complicated chain of chemical reactions and physical transfers, and proceeds very slowly. It is obviously essential to understand the mechanism by which carbon dioxide is interchanged between air and ocean, and what controls the rate of this process, if future trends in the atmospheric concentration of this gas are to be predicted.

102. A recent report to the Joint Organising Committee of the Global Atmospheric Research Programme, which is sponsored by the World Meteorological Organisation (W.M.O.) and International Council of Scientific Unions, stressed that the effects of a change in atmospheric carbon dioxide content on the radiation balance of the earth are still not understood. The best available calculations suggest, however, that a doubling of the present carbon dioxide content of the atmosphere would raise the temperature at the earth's surface by about 1.3° Centigrade (C). This would happen because the carbon dioxide in the air has a so-called "greenhouse effect": like a glass pane it lets through most of the visible radiation reaching the atmosphere from the sun but it stops some of the long-wave radiation emitted back into space from the earth's surface. The result is that the earth retains more heat.

103. If the present increase in atmospheric carbon dioxide is indeed largely due to the burning of fossil fuels, as seems plausible, and if something like 50 per cent of the amount released remains in the air, then the levels of carbon dioxide in the atmosphere may be expected to reach about 365 ppm in 30 years' time and cause warming by about 0.1 to 0.2°C. Such a rise in temperature is unlikely to be significant. These figures are tentative, and cannot become more precise until more advanced mathematical models of the problem have been developed.

Accurate prediction will obviously also demand a precise estimate of future fuel consumption. In the longer term, the United States Council on Environmental Quality has suggested that if all the fossil fuel reserves of the earth were burned, and half of the resulting carbon dioxide retained in the atmosphere, the earth's average temperature might increase by 2 to 3°C. Were this to happen considerable areas of polar ice would begin to thaw, with a consequent rise in sea level. But such eventualities are not only remote: they are conjectural. Before they could ever begin to take effect new mathematical techniques, better observations, improved understanding of the carbon dioxide cycle in air and sea and more powerful computers should have allowed more precise predictions and a better appraisal of the real extent of the problem.

104. A strong case can be made for measuring the carbon dioxide in the air at more than the present two points and, because of the importance of the ocean as a repository for carbon dioxide, some of these additional sampling points should be located in oceanic areas. The W.M.O. has recently proposed that a widely-spaced network of baseline stations should be established in places remote from local sources of pollution in all the main climatic zones of the earth. The Meteorological Office has suggested to the W.M.O. that the existing observatory at Lerwick in the Shetland Islands might serve as one of these stations. We support this proposal and suggest that some of the meteorological stations which Britain maintains in the Antarctic and elsewhere in the world might also find a place in the programme.

105. The fundamental atmospheric chemical and physical processes involving the carbon dioxide balance are still inadequately known. Its natural distribution between the different climatic zones and, within each, between air, water and living creatures, requires further study. We need to know how far there are natural variations in the production of carbon dioxide and how far green plants, which remove it from the air in the process of photosynthesis, are likely to respond to its increasing concentration, thus possibly providing a compensating mechanism. More detailed basic research is also needed on how changes in the carbon dioxide level affect the penetration of radiation through the atmosphere.

Possible effects of dust (including aerosols) released into the atmosphere

106. It has been suggested that the dust content of the atmosphere is increasing because of man's industrial and agricultural activities. The air is certainly more hazy and dusty in and around urban and industrial areas. Forest fires (most of which are now due to man) can also release great amounts of dust and fine ash. But there is no firm proof that the haziness of the air has increased generally over the world. Only one series of measurements has been made at a point which is really remote from large industrial areas—the summit of Mauna Loa, Hawaii. This record reveals the ejection of great quantities of fine dust from volcanic eruptions, especially that on Bali in 1963. Also, during the later 1960s the records showed a rise in the general dust level which was thought to be due to pollution; by 1970, however, the turbidity of the air over Hawaii had returned almost to the 1962 level. Other measurements purporting to show a steady rise in the dust content of the atmosphere, made at Washington D.C., U.S.A. and Davos, Switzerland, are suspect because these places are not really remote from industrial areas. There is no convincing evidence that human activities have so far increased

the general turbidity of the atmosphere appreciably, but it is quite clear that great volcanic eruptions can have a considerable temporary effect.

107. Dust added to the atmosphere by man's activities could have several effects. It might produce more nuclei about which water vapour could condense or freeze to form rain droplets or ice particles. This in turn might make the skies more cloudy, and cause some clouds to shed rain or snow either earlier or later than they would otherwise have done. Dust might also have a more direct effect by screening out incoming solar radiation. It has been calculated that a 10 per cent increase in atmospheric turbidity could result in a decrease of 0.8 per cent in the amount of energy absorbed by the earth's atmospheric system. This would cause a cooling of the climate by about 1°C., about five to ten times as much as would be produced by a 10 per cent increase in atmospheric carbon dioxide. However, the dust itself would absorb radiation from both sun and earth, which would have something of a compensating effect.

108. The possible significance of changes in the amount of dust in the air cannot be assessed until we have much more reliable measurements. These are difficult to obtain because the dust load of the atmosphere varies enormously from place to place, and time to time, as a result of both natural processes and man's activities. Analysis of records of incoming radiation, made over many years at weather stations remote from industrial centres, may help to determine whether atmospheric turbidity has really increased. We therefore welcome a proposal by the Meteorological Office to scrutinise the records for Lerwick and similar stations, and we recommend that the U.K. delegation to the W.M.O. should press for comparable action elsewhere. We consider that if reliable standardised methods can be developed it might also be valuable to measure the amount of dust in the air above the baseline stations proposed by the W.M.O. Finally, we consider that further research is needed on the effects of dust in the air on cloud formation and on incoming and outgoing radiation. Only when we have more rigorous measurements of the dust content of the air, and an improved understanding of its effects, will it be possible to develop mathematical models to make reliable predictions of the likely significance of this dust as a modifier of climate.

Effects of water vapour

109. The stratosphere contains very little water vapour and the exchange of air between the stratosphere and lower levels of the atmosphere is slow. Consequently, if high-flying supersonic aircraft discharge even modest amounts of water vapour into the stratosphere, there could be a detectable effect. It has been calculated that if 400 supersonic aircraft each made four flights per day, and if the water vapour they released remained on average for 10 years (which it seems unlikely to do), the effect might be to double the existing water content of the stratosphere and to raise the temperature at the earth's surface by about 0.6°C. because of a greenhouse effect (paragraph 102).

110. It is most unlikely that this water vapour would create clouds in the stratosphere and so reduce the radiation reaching the ground. On the other hand, aircraft do form condensation trails at lower levels (in the upper troposphere) and these can sometimes be seen to spread out into fairly extensive sheets of cirrus cloud. Since, however, the rate of exchange between the air in these

lower layers is quite rapid, water vapour injected into the troposphere by aircraft is likely to remain there for only a few days. Near Denver, Colorado, the average coverage of the sky by cirrus cloud is said to have increased by about one-tenth since 1958, but this is near a busy air lane. Intense air traffic occurs only over a very limited proportion of the globe and is considered unlikely to lead to any general increase in cloudiness and so affect world climate. Nonetheless we believe that a watch should be kept on the situation.

Effects of exotic chemicals

111. It has been suggested that exhaust gases from rockets may pollute the upper atmosphere and produce changes which might affect the layer of ozone which protects the earth's surface from harmful ultra-violet radiation. This fear arises because rockets might release into the high atmosphere certain elements or compounds that are normally very rare or absent there. The screen against ultra-violet radiation depends on concentrations of ozone as low as a few parts per million, and the formation and maintenance of ozone depends on complex chemical processes which might be upset by pollutants.

112. There is no observational evidence that any such changes are occurring. No theoretical suggestions of specific chemical or physical processes involving pollutants, known or expected to occur in rocket exhaust, and leading to such severe consequences, have been advanced. While the possibility of such developments must not be ignored (and we accordingly welcome the concern recently expressed by the W.M.O.), we accept that it would not be appropriate or feasible to begin a new research programme specifically on this topic at present. Nonetheless, we consider that the possibility of such changes adds strength to the case for more research on the chemical and physical processes involved in maintaining the natural balance of atmospheric constituents. In this research, the possible effects of elements and compounds normally rare or absent in the upper atmosphere should not be ignored.

Effects of changes in land use on climate

113. The atmosphere receives most of its heat and all of its water vapour through the boundary layer at the earth's surface. Conditions at this boundary can be altered by the way man uses the land. The degree to which radiation is reflected from the ground surface depends on the nature and extent of the vegetation cover. One of the most dramatic differences is that between forested and open ground under snow. A forest presents a dark surface to incoming radiation and absorbs much of it because snow soon falls off the trees to expose branches or foliage. Surrounding fields retain a snow cover much longer and consequently reflect incoming radiation. Evaporation from bare ground can also be very different from that from areas covered by vegetation; this can in turn affect the heating of soil and air. Over vegetation which is transpiring, a large fraction of the incoming heat is used up in evaporation. Where, on the other hand, the ground is bared (as in arable areas in spring), there may be much less evaporation and more heat available to warm ground and air.

114. The clearance of forests and their replacement by grassland or cultivation thus causes changes in the local pattern of heating of ground and atmosphere. Generally, such changes are likely to cause regional rather than world

alterations in climate. Their effects cannot be precisely assessed without extensive surveys of land use, fairly accurate predictions of future land-use trends, more detailed information than we now have about the capacity of different kinds of ground and vegetation to reflect radiation and lose water by evaporation, and more advanced mathematical models. We hope that the development of such models is given priority so that attention can be given to these problems.

115. Recently, there has been considerable discussion of the ways in which world climate might be affected if the water of several major rivers in the U.S.S.R. were diverted to flow to the Aral and Caspian Seas, rather than the Arctic Ocean. If this increased the salinity of the Arctic Ocean and hence reduced the formation of sea ice over an appreciable area, there might indeed be a detectable effect. This cannot be quantified without a deeper understanding of the basic dynamics of the atmosphere and better methods for predicting changes and we emphasise the need for basic research in this field.

Direct effects of industrial and domestic energy consumption

116. It has been known for many years that cities tend to be warmer places than the surrounding countryside because of the heat produced in homes, factories and other buildings. On average, the difference in warmth is around 1°C. but under certain conditions it may be even greater. It has been suggested that, as cities become larger and power consumption grows, this effect may become detectable on a world scale. However, even in Britain, which is one of the most densely populated and industrialised countries in the world, man-made heat energy of this kind accounts on average for only about 0.75 per cent of the total heat energy which is radiated into space from the ground surface and atmosphere over the country as a whole. Much larger variations in heat energy of this kind occur as a result of natural changes in sea temperature. Taking the large tracts of sea and unpopulated land into account, it seems clear that it will be a very long time before direct thermal pollution of the environment reaches the point at which it could have a detectable effect on world climate.

Natural long-term variations in climate

117. In this, as in many other aspects of pollution, the significance of man's activities can be assessed only when we have an adequate basic knowledge of the structure and dynamics of the natural unpolluted environment. It is clear from the preceding paragraphs that atmospheric pollutants, if they affect world climate at all, will do so, not because they are released in such bulk that they directly cause gross changes in the composition or structure of the atmosphere, but, more subtly, through their modification of its normal processes. Many of these processes are on such a scale that the effects of pollution could readily be masked. For example, although the increasing levels of carbon dioxide in the air might suggest that the world should have become steadily warmer over the past century, in fact there has been a general cooling over the last ten years, at least in the northern hemisphere. Some people have attributed this to the effect of pollutant dust in screening out incoming radiation. But we know from the study of sediment cores extracted from the deep ocean, ice cores from Greenland and the Antarctic, peat preserved in bog and fenland basins, and the careful collation of accounts of weather through historic times, that the climate

of the earth showed as great or greater fluctuations long before it could have been affected by man. We believe that the study of such long-term natural climatic changes and of their possible causes is an essential background to the work on pollution which we recommend, and we are glad to note that this is going on both within the Meteorological Office and at many universities in Britain, as well as in many other countries.

Conclusions and recommendations

118. The information we have summarised in this chapter gives no reliable answer to the questions people ask about the long-term global effects of changes in carbon dioxide, dust and water vapour in the upper atmosphere. In the next decade or so man-made pollution by these substances will not cause significant changes in the natural environment; but there is sufficient uncertainty about the long-term effects to make it essential that research into the influence of these factors on world climate should continue.

119. More measurements should be made of the amount of carbon dioxide, dust and other pollutants in the atmosphere, at points remote from local sources of contamination. Changes in cloud cover, and in the amount of radiation reaching the earth's surface, should also be watched, possibly with the aid of satellites. We support the proposals by the W.M.O. for a widely-spaced series of baseline stations at which pollutant levels would be measured, and we welcome the suggestion by the Meteorological Office that the Observatory at Lerwick in the Shetland Islands be developed as one of these. We also suggest that some of the meteorological stations maintained by Britain overseas, for example in Antarctica, might also be included in the programme.

120. Our knowledge of the chemical and physical processes within the atmosphere and at the interface between air and ocean is still inadequate. Without this knowledge full advantage cannot be taken of mathematical techniques. Much of the research that is needed will be of a fundamental character; while we hope that the Meteorological Office will continue to make a contribution to it, a great deal may be more suitable to universities.

121. We emphasise that the impact of pollutants on the climate of the earth can only be assessed if we have an adequate knowledge of natural long-term oscillations and the processes which cause them. We therefore consider it important to maintain research in this field.

122. We consider that the research by the U.K. on the effects of pollution on weather and climate should be planned in collaboration with that of other countries and with international agencies, especially the W.M.O. We know that several other international bodies are at present developing plans for world-wide monitoring of atmospheric pollutants; we believe, however, that it is essential that they co-ordinate their activities, eliminate duplication and produce a single scheme. On the evidence available to us we consider that the W.M.O. is the most appropriate body to run that section of the scheme which is concerned with monitoring the background pollution of the atmosphere and assessing its effects.

123. Finally, we wish to emphasise that, because of the size and complexity of the atmosphere, its study demands the development of new and more sophisti-

cated mathematical models which will, through the use of advanced computers, allow us to simulate large-scale and long-term atmospheric processes and the ways in which these may be modified by pollutants. We welcome the emphasis that has been given to the development of mathematical models in the Meteorological Office, which will, in 1971, have at its disposal a very powerful new computer, part of the time of which can be used for climatological research. We hope that the Office will continue to give high priority to this part of its work. We believe that, if there is a continuing improvement also in the quantity and quality of factual information and in the theoretical understanding of atmospheric processes so that the models themselves can be improved, we shall soon be able to evaluate much more exactly the magnitude of the possible problems for the future.

SUMMARY

The task

124. (1) As a standing Royal Commission with no specific or restricted task and independent from Government, our first duty will be to keep track of what is happening throughout the natural environment in order to ensure that concern for these issues is sustained by informed public opinion (*paragraphs 1–2*).

(2) Much has already been done in Britain, and is being done, to safeguard our environment, but there is no ground for complacency. There is a need for objective and realistic advice on the difficult choices which must be made in deploying limited resources (*paragraphs 3–6*).

(3) We shall recommend action where appropriate and identify areas where more information is needed; publish reports on special features of the environment; and suggest ways of developing co-operation with other countries (*paragraph 7*).

(4) It is not our task to deal with appeals against local or central Government decisions on specific cases; and we shall not concern ourselves directly with the domestic or working environment (*paragraphs 9–10*).

(5) The quality of the environment is also affected by considerations outside our terms of reference: increase in population, technological advance, the rise in national product and the spread of derelict land. All these factors require planning and should be taken into account within a comprehensive policy for safeguarding the environment (*paragraph 11*).

The pollution problem

125. (1) The problem is how to strike a balance between the benefits gained from economic and technological achievements and what is being lost in terms of deterioration of the environment (*paragraphs 12–14*).

(2) Pollution's main economic characteristic is that its costs are not usually borne by the polluters, so that production is often pushed beyond the socially optimum point; there is inadequate incentive to allocate sufficient resources to reducing pollution; and certain producers and consumers benefit at the expense of the victims of the pollution (*paragraphs 15–16*).

(3) In principle, the amount of resources devoted to reducing pollution in general, as compared with other claims, or to the abatement of specific kinds of pollution, should depend on the relevant costs and benefits (*paragraphs 17–22*).

(4) There are, however, great difficulties in making such calculations so that, while they provide a valuable aid to decision-making, one should not be too mechanical in applying them, or be too purist about abstaining from decisions in their absence. In the end, the decisions must still reflect subjective value judgments (*paragraphs 23–25*).

(5) Some forms of pollution can be controlled only by local and central Government and the efforts of industry. But much can be done by the individual citizen. In principle, no one should have the uncontrolled right to contaminate the environment. What is needed is a combined operation by public opinion, economic incentive and legislation (*paragraphs 26–29*).

The state of the environment

126. A comprehensive policy for the environment must be based on hard facts and estimates of cost-effectiveness, as well as an assessment of what the public want and are prepared to pay for, both for themselves and for future generations. In this context we distinguish between the priorities for action now and for further enquiry (*paragraphs 30–35*).

127. As a basis for assessing these priorities we summarise recent trends in the state of the natural environment in Britain and in some of the common pollutants (*paragraphs 36–71 and Figures 1–12*). The success of the clean air policy is encouraging but more needs to be done to apply this policy throughout the country and to enquire into the effects of pollutants from road vehicles. There are possible long-term effects of atmospheric pollution on global weather and climate. Pollution of the land continues; domestic refuse and industrial waste of all kinds, and particularly toxic materials, are an ever-increasing problem; there is need to accelerate the trend towards the use of less persistent pesticides; valuable manure from intensive farming is wasted. Not only is the state of some of our rivers depressing: too many of them are so polluted that they cannot be used to meet our growing needs for water. The estuaries and inshore seas are increasingly treated as an open drain and dumping ground. Oil pollution of the sea is still substantial and the danger of tanker accidents remains; waste disposal to the sea and exploitation of the sea floors are causing international concern. The disposal of radioactive waste, though satisfactory at present, will need more attention for the future. And noise is rapidly becoming one of the most disturbing features of modern society.

Global effects of atmospheric pollution

128. We set out the results of our review of the first problem referred to us by the Government: the adequacy of current research into the possible long-term effects of atmospheric pollution on weather and climate. **We see no cause for alarm or for "crash" programmes of research. But we recommend the extension of international monitoring of the atmosphere and the maintenance and extension of fundamental research on an international basis on the natural chemical and physical processes, both within the atmosphere and between the atmosphere and the surface of the planet** (*paragraphs 118–123*).

Choice of priorities

129. Among the **priorities for action** (*paragraph 72*) on which the Government have already had (or will shortly receive) authoritative advice, there are issues on which we would like to see prompt action by the Government and others concerned:

(1) Provision to meet the increased demand for water, for example by improved sewage treatment.

(2) Control of the disposal of solid and semi-solid toxic wastes on land.

(3) The control of dumping of noxious materials at sea.

(4) The reduction of noise.

130. There are certain **priorities for enquiry** which seem to be receiving attention elsewhere and which, despite their importance, we do not propose to tackle ourselves, though we shall be concerned to see prompt and effective decisions on all these matters. Examples are further developments in clean air, the study of long-term exposure to emissions from motor vehicles and of the disposal of farm wastes, and improved control of oil pollution at sea (*paragraphs 74–81*).

131. But there are **other problems which need more attention** than they are getting at present:

(1) The economics of pollution control (*paragraphs 83–84*).

(2) The qualifications and training of those who control air and water pollution (*paragraph 85*).

(3) The pollution of tidal waters, estuaries and the inshore seas (*paragraph 86*).

(4) The international development of improved techniques for monitoring pollution (*paragraphs 87–88*).

(5) Continuing appraisal of all pesticides used in this country; the replacement of more persistent types as rapidly as possible; the desirability of mandatory control and the need for the Government to make their policy known on this question (*paragraphs 89–90*).

(6) Planning ahead for the future disposal of increasing amounts of radioactive waste (*paragraph 91*).

Conclusions

132. Our proposals for our own work in the coming year are:

(1) **The Commission should first enquire into and report on the problems of pollution of tidal waters, estuaries and the seas around our coasts** (*paragraph 93*).

(2) **The Commission should keep under review action to improve Britain's rivers.** We regard three issues as particularly important:

(i) the integration under a single authority in each river region of the administration of rivers and sewage treatment;

(ii) the improvement of qualifications and training of those who control water pollution; and

(iii) the application of up-to-date process and chemical engineering to the design and operation of sewerage and sewage plant (*paragraph 94*).

133. **We also recommend that the Government should make suitable arrangements for a start to be made on a study of the costs of different degrees and kinds of pollution and of pollution abatement; the extent and manner in which different sources contribute to pollution; and the likely trends in these sources** (*paragraph 95*).

. . . . . .

Summary

134. We wish to record our indebtedness to our Secretary, Miss D. M. Wilde, and to Mr. A. C. Parsons, our Assistant Secretary, and their staff for the skill and thoroughness with which they have served the Commission in our first year, and especially for the devoted work which they have put into the preparation of our first Report. It is a pleasure also to thank Dr. M. W. Holdgate, who is now head of the Central Unit on Environmental Pollution in the Department of the Environment, for the generous help which he and his unit have given us in collecting some of the information on which this Report is based.

ALL OF WHICH WE HUMBLY SUBMIT FOR YOUR MAJESTY'S GRACIOUS CONSIDERATION.

ERIC ASHBY (*Chairman*)
LAUNCELOT NORVIC:
S. ZUCKERMAN
JOHN WINNIFRITH
FRANK FRASER DARLING
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A. BUXTON
WILFRED BECKERMAN
VERO WYNNE-EDWARDS

D. M. WILDE (*Secretary*).
A. C. PARSONS (*Assistant Secretary*).
16th February, 1971.

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