ROYAL COMMISSION
ON
ENVIRONMENTAL POLLUTION

CHAIRMAN: SIR HANS KORNBERG

SEVENTH REPORT

AGRICULTURE AND POLLUTION

Presented to Parliament by Command of Her Majesty
September 1979

LONDON
HER MAJESTY'S STATIONERY OFFICE
£6 net

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ROYAL COMMISSION
ON
ENVIRONMENTAL POLLUTION

SEVENTH 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.

"He gave it for his opinion; that whoever could make two ears of corn, or two blades of grass to grow upon a spot of ground where only one grew before; would deserve better of mankind and do more essential service to his country than the whole race of politicians put together."

Jonathan Swift (1667–1745): *Gulliver's Travels, Voyage to Brobdingnag. Chapter 7*

"If the changes that we fear be thus irresistible, what remains but to acquiesce with silence, as in the other insurmountable distresses of humanity? It remains that we retard what we cannot repel; that we palliate what we cannot cure".

Samuel Johnson (1709–1784): *Preface to Dictionary of the English Language.*

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CHAPTER 1

INTRODUCTION

The choice of the study

1.1. Agriculture and the environment are indissolubly linked. To a substantial degree, the natural environment is the agricultural workplace and is shaped by agricultural activities. Throughout its long history, farming has necessarily changed the environment and some of these changes have been harmful; for example, ploughing has often resulted in soil erosion and the removal of forests has sometimes led to destructive flooding. Nevertheless, for centuries farming has been practised by methods that appeared generally to be in stable harmony with nature. The belief that wise husbandry goes hand in hand with environmental good is deeply embedded.

1.2. This belief has been increasingly called in question by the changes in agricultural practices that have taken place over the last few decades. We describe some of these changes in some detail in subsequent chapters; here we simply note some of the salient trends. Mechanisation has increased and economic forces have required farmers to seek more efficient and cheaper techniques of production, so that there has been a continuing loss of agricultural labour. For example, according to figures supplied by the Ministry of Agriculture, Fisheries and Food (MAFF), in arable farming one person can now work an average of 81 hectares* of arable land compared with an average of 16 hectares as recently as 20 years ago. The introduction of specialised machinery has made possible and even necessary a larger scale of operations while there have emerged pronounced regional differences in the kinds of farming practised. Farm businesses have become bigger but less diverse in their range of activities; the number of different activities on individual farms has dropped by rather more than half since the war. Similar trends are evident in animal husbandry: herd sizes have increased and more of our livestock, particularly pigs and poultry, are kept in bigger intensive units. These trends are expected to continue.

1.3. Many of these changes in the structure of agriculture have been made possible and are sustained by the increasing application of science and technology to agricultural processes. Among those of special interest to us in connection with our study are the great increases that have occurred in the use of chemicals (the so-called agrochemicals), and of inorganic fertilizers. These chemicals have made possible fundamental changes in farming systems

*1 hectare=2.47 acres. One hectare is an area equal to that of a square of side 100 metres, ie about 110 yards: it is roughly half as much again as a football pitch of regulation size.

and have been largely responsible for the remarkable increases in crop yields that have been achieved in recent decades.

1.4. Farming, long regarded as a way of life, is now becoming as much an industry as many other businesses. Although the vagaries of the climate and the market will persist, increasing mechanisation and automation, improved crop varieties, more precise chemical treatments and better facilities for handling, processing and storage, offer the prospects of a programmed approach to crop production in which the nature and timing of the operations needed to grow produce of a pre-determined quality can be specified more precisely. Similarly, in livestock farming, the development of more productive breeds, the improved understanding of nutritional requirements, the elaboration of techniques for keeping livestock under environmentally controlled conditions and other technical developments have made it possible for output to be increased.

1.5. However, the intensification of agriculture over the past few decades has greatly increased its potential to cause pollution. The White Paper "Food from Our Own Resources" (1975)([1]) which set out the previous Government's policy for the expansion of food production in the UK over the succeeding five to ten years, held that the objective of agricultural policy should be a continuing expansion of the net product of the industry at an average rate of about 2½ per cent a year. The review of the medium-term prospects for agriculture in the White Paper "Farming and the Nation" (1979)([2]) indicated that a policy of selective expansion would be maintained. Since there is a continuing loss of agricultural land to urban and other developments, such a policy can be realised only through further intensification of agriculture, with the possibility of increased pollution risks in the future. And, because a high proportion of the land in the UK is being actively farmed, such polluting effects of intensification may have a correspondingly wide impact.

1.6. In agriculture as in other industries full account should be taken of the polluting potential of new policies and practices. It was not evident to us, when we first considered whether to embark on our study, that this was being done. We noted, for example, that there was little more than a passing reference to pollution in "Food from Our Own Resources" (1975), even though the projected annual expansion of the net product would amount to an increase of nearly 30 per cent in ten years and the pollution implications might be of the same order. The 1979 White Paper stated that the projected expansion can be achieved "without undue impact on the environment" but without evidence for that view; it noted that agriculture may cause pollution, and be affected by pollution from other sources, and that we were currently enquiring into these matters.

1.7. In the context of pollution the concept of "good agricultural practice" is of prime importance. This term is embodied in the Control of Pollution Act 1974. Section 31 of the Act provides that a farmer will not be guilty of an offence under that section (which relates to the control of water pollution) if he can show that he was operating in accordance with good agricultural practice; for the purposes of this provision, a code of practice approved by Agricultural Ministers would be a sufficient definition. A further provision of the Act enables a water authority which believes that a particular practice has caused, or is likely to cause, pollution, to request the Secretary of State for the Environment to serve notice on a farmer to avoid or modify that practice. Where such a request is upheld, the defence of good agricultural practice no longer applies. Nevertheless, water authorities are concerned that the provisions of the Act may be held to place agriculture in a special position in relation to pollution: there is the possibility that, in conflicts between agricultural and pollution considerations, the former may be regarded as paramount.

1.8. In our view, it is important that pollution should be considered in the formulation of the codes of practice that define "good agricultural practice". Before embarking on our study, we explored this point among others in a preliminary discussion with MAFF. We were not persuaded that sufficient attention was being paid to the pollution that might be caused by agriculture. That problems might arise was recognised, but we were left with the impression that such problems were regarded as secondary in importance and as unavoidable concomitants of food supply. The approach appeared to us to beg the real question: whether the changes that have occurred, or are likely to occur, in agricultural practices are such as to call for new attitudes in dealing with the consequential problems of pollution or even, perhaps, for some constraints on these practices.

1.9. The impression that good agricultural practice is independent of considerations of pollution emerged from the report "Inquiry into pollution from farm waste"(3), prepared by the Advisory Council for Agriculture and Horticulture in England and Wales (ACAH). The Council is composed of distinguished agriculturalists and horticulturalists together with a senior MAFF official; it is required to advise on such matters as may be referred to it by the Minister, and these may relate to broad questions of agricultural policy or more detailed matters. In discussing the application of the "polluter pays" principle to agriculture, the Council commented: "A strict application of the principle could therefore mean that a farmer might be required to bear the cost of control measures imposed on him, or have restrictions imposed on his activities, for, say, social reasons, when in terms of good agricultural practice these measures are not necessary." The ACAH report was written from the viewpoint of the farming community and was not intended to be a study of the total impact of agricultural practices on the environment. We concluded that the report should not deter us from our projected study although the information it contained, particularly in its discussion of farm wastes, provided a valuable start for our own enquiries.

1.10. On the basis of our preliminary consideration of these issues, we decided that it would be timely to undertake a study of the pollution implications of the changes that have occurred in agriculture, and also of likely future developments. We recognised that while, like other industries, agriculture may cause pollution, it is also more vulnerable than most industries to pollution from other sources. Certainly it appeared from evidence we subsequently received that in the view of farming bodies, agriculture (in pollution terms) is more sinned against than sinning. We therefore decided that we should consider also the effects of pollution, from urban and industrial sources, on agriculture itself. We announced our intention to undertake the study in February 1977.

1.11. We have excluded from our study the pollution caused by food processing industries. We have also excluded from our study the pollution caused by the increasing practice of on-farm processing of foodstuff since it appeared to us that the undoubted problems that can arise can be dealt with satisfactorily under existing control arrangements. We have taken agriculture to include horticulture and forestry. We have excluded consideration of the effects on fish and shellfish of pollution of estuaries, coastal waters and the sea, partly because this would have made the study unmanageably large and partly because these issues had been considered previously by the Commission([4]). But we decided that we should take some account of the practice of fish farming in inland waters. A Parliamentary written answer([5]) stated that the definition of agriculture in the Town and Country Planning Act 1971 included "the breeding and keeping of livestock, including any creature kept for the production of food" and thus appeared to cover fish farming. Perhaps more important, we knew that fish farming is a rapidly growing business which appeared to pose problems of some concern to water authorities.

1.12. In announcing our study, we stated our intention to consider not only agricultural pollution problems as they exist but also what might develop in the future, taking for our time scale the period up to about the end of the century. We proposed also, where it appeared relevant and useful, to compare the practices and policies adopted in the UK to deal with agricultural pollution with those adopted elsewhere, especially in Europe. At the start, we identified three main areas to be covered by the study. The first was the effect on water supplies and on the natural environment of farm effluents or run-off from agricultural land and in particular the leaching of manures and fertilizers; associated with this is the effect of industrial or urban pollution on the availability of water supplies for farming. Our second area was the environmental consequences of the use of crop protection chemicals. The third was the issue of planning in relation to agriculture, with special reference to the pollution problems posed by intensive livestock units.

1.13. Our terms of reference imply that we are principally concerned with physical pollution of the environment; thus, in the context of agriculture, we emphasise the effects of farm chemicals on the environment and the problems that arise from intensive livestock units. For example, the use of chemicals in agriculture has had well-documented adverse effects on wildlife; their use has contributed to the decline in populations of many species of animals and of birds. And, although no arable weed has yet become extinct through the use of herbicides, some are reported to be close to that condition([6]). Modern agriculture also affects the environment in other ways, raising issues which fall outside our terms of reference. For example, it is generally acknowledged that the chief impact of agriculture on wildlife lies in the continuing loss of species habitats brought about by increasing specialisation, mechanisation and the striving for increased production; one consequence of this is the progressive removal of hedges and hedgerow trees. Since the Second World War, the countryside has been radically altered by such developments and the end of the process is not in sight. Indeed, the erosion of wildlife habitats may accelerate. For instance, it is now feasible to turn much of the grazing land of the Somerset Levels into arable land by lowering the water table, with important and potentially deleterious consequences for wildlife. The effects of agricultural development on wildlife were assessed by the Nature Conservancy Council (NCC) in "Nature conservation and agriculture"([7]) where the Council concluded that Britain faces a serious reduction in wildlife if present trends continue.

1.14. We are aware that measures that we might propose on pollution grounds might interact with proposals made by other bodies from a different standpoint. We have, therefore, informed ourselves whenever possible of the views expressed on wider issues by such other bodies and, in particular, have taken note of the NCC report referred to above and of the more recent reports by the Countryside Review Committee on "Food Production in the Countryside"([8]) and the ACAH on "Agriculture and the Countryside"([9]).

1.15. Another aspect of the environmental impact of agriculture is its effect on amenity, especially the visual and aesthetic effects of agricultural developments such as the removal of trees or hedges and the erection of modern farm buildings which because of their size or design may appear out of keeping with their setting. We do not dispute the importance of these issues, but they are excluded from our study.

1.16. Another matter raised in evidence submitted to us relates to the practices used in intensive livestock units, especially to the close confinement of animals which may prevent them from turning round or, in the case of poultry, from freely flapping their wings. Many people hold strong objections on moral grounds to such practices and there has been some dispute about whether the practice is degrading and cruel or whether, on the contrary, it may be regarded as beneficial to the animals concerned. The matter was fully considered by a committee appointed by MAFF under the late Professor F W Rogers Brambell, which reported in 1965([10]) and which made recommendations for animal welfare that were subsequently embodied in codes of practice issued by Agricultural Ministers. Although this subject is clearly beyond the scope of a body concerned with environmental pollution, we visited intensive units during the course of our study to discuss the problems of waste disposal, and saw something of the conditions under which animals are kept. In some cases we found these conditions repugnant. We consider that there is a need to review the extent to which the codes of practice prompted by the Brambell

Report are being followed. We welcome the Government's announcement that a Farm Animal Welfare Council is to be set up to advise the Minister on legislative or other changes necessary to protect animals on farms, at markets or in transit. We hope that our views on this matter will be taken into account by the new Council.

1.17. It has been suggested that the use of antibiotics and hormones to promote animal growth may damage human health by the transmission of residues through food chains, and that there is a risk that the repeated use of antibiotics in small doses could lead to the emergence of drug resistant strains of bacteria. This issue was fully examined in the Swann report([11]) and we have therefore excluded it from our study.

1.18. We have taken our study to cover the United Kingdom as a whole. The main bulk of the evidence submitted to us originated from bodies whose responsibilities cover either England or England and Wales, but we have also encouraged and received evidence from organisations, official and otherwise, in Scotland and Ulster. We are conscious of the fact that very few references appear in this report to agricultural practices in either Scotland or Northern Ireland. This is due only to the need to simplify the text wherever possible. We have considered the practices in those two countries (both of which we visited) and they are referred to where they differ markedly from those in England and Wales. Generally our conclusions apply throughout the UK.

Method of Study

1.19. We invited evidence from the many official organisations we knew to have an interest in our study and also from the general public. (A list of those who submitted evidence is given in Appendix 2.) We also visited different areas of the country and a number of institutions in the UK and on the European mainland to gather information and to examine agricultural practices at first hand. (Details of our visits are given in Appendix 3.) In this report we have abbreviated the names of organisations frequently mentioned by their initials (Appendix 4).

1.20. We wish here to express our gratitude to those who submitted evidence or who assisted in our visits. We greatly appreciate the willing help we invariably received, the more so in the case of those principal bodies to whom the work entailed by our investigations must have been a considerable burden. We owe a particular debt of thanks to MAFF which, as the Government Department most involved with our study, bore the brunt of our enquiries.

CHAPTER II

CHANGES IN AGRICULTURE

Introduction

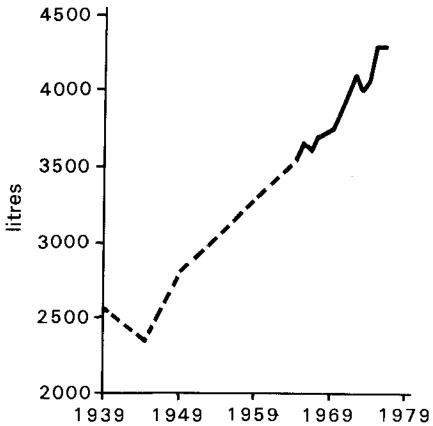
2.1. In this chapter we describe the changes that have taken place in agriculture in the UK during the past few decades that are relevant to our purpose. These include the changes that have arisen from the increased use of agricultural chemicals, the intensification of farm activities and the trend towards specialisation. The impact of these changes is evident from the basic data on agricultural output and productivity presented in Table 2.1 and Figures 2.1a, b, & c. It will particularly be noted that the output of many crops has increased dramatically although the area of land under cultivation has declined slightly. Similarly, farm animals have become more productive, as indicated by the yields of milk and eggs.

TABLE 2.1

Home production of crops and livestock in the UK

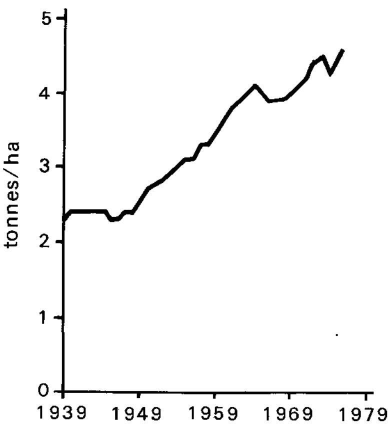
			1952	*1977*
1.	Area of agricultural production ('000 ha) (Crops and grass excluding rough grazings)		12,616	11,989
2.	Numbers of those engaged in agriculture ('000)		869	373·2
3.	Production			
	Wheat	('000 tonnes)	2,344	5,274
	Barley	,,	2,371	10,531
	Oats	,,	2,816	790
	Potatoes	,,	7,974	6,621
	Sugar	,,	587	949
	Beef and Veal	,,	606	1,032
	Mutton and Lamb	,,	168	229
	Pork	,,	153	650
	Bacon and Ham	,,	397	218
	Poultry Meat	,,	86	678
	Butter	,,	18	134
	Cheese	,,	64	206
	Milk for liquid consumption	(mill litres)	7,617	7,485
	Eggs	(mill dozen)	688	1,156
4.	Yields			
	Wheat	(tonnes/ha)	2·85	4·90
	Barley	,,	2·57	4·39
	Oats	,,	2·41	4·06
	Sugar	,,	4·35	5·40
	Potatoes	,,	19·90	28·50
	Liquid Milk	(litres/dairy cow)	2,734	4,452
	Eggs	(per hen)	145	240·5

Figure 2.1a
Annual Average Milk Yield per Dairy Cow in England and Wales



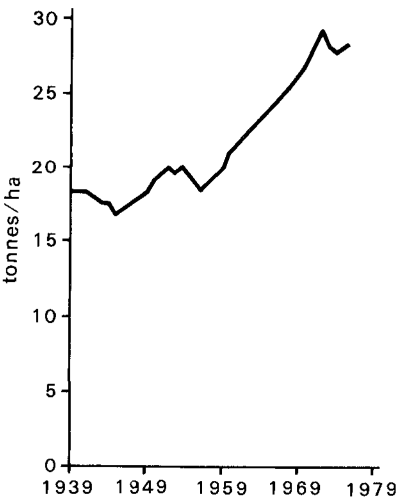
SOURCE: Milk Marketing Board, 'Dairy Facts and Figures'

Figure 2.1b
Wheat Yields in Great Britain - 5 year average



SOURCE: MAFF

Figure 2.1c
Potato Yields in Great Britain - 5 year average



SOURCE: MAFF

2.2. In this chapter, we discuss the pollution aspects of agricultural practice that appear especially to need attention now and in the years immediately ahead. We comment in passing on the diversion of agricultural land to other purposes, and on fish farming. However, we also consider a possible pattern of agriculture in the UK by the end of the century, having in mind that, with the passage of time and with the further advance and application of technology, pollution problems could intensify so as to impose important burdens on the environment.

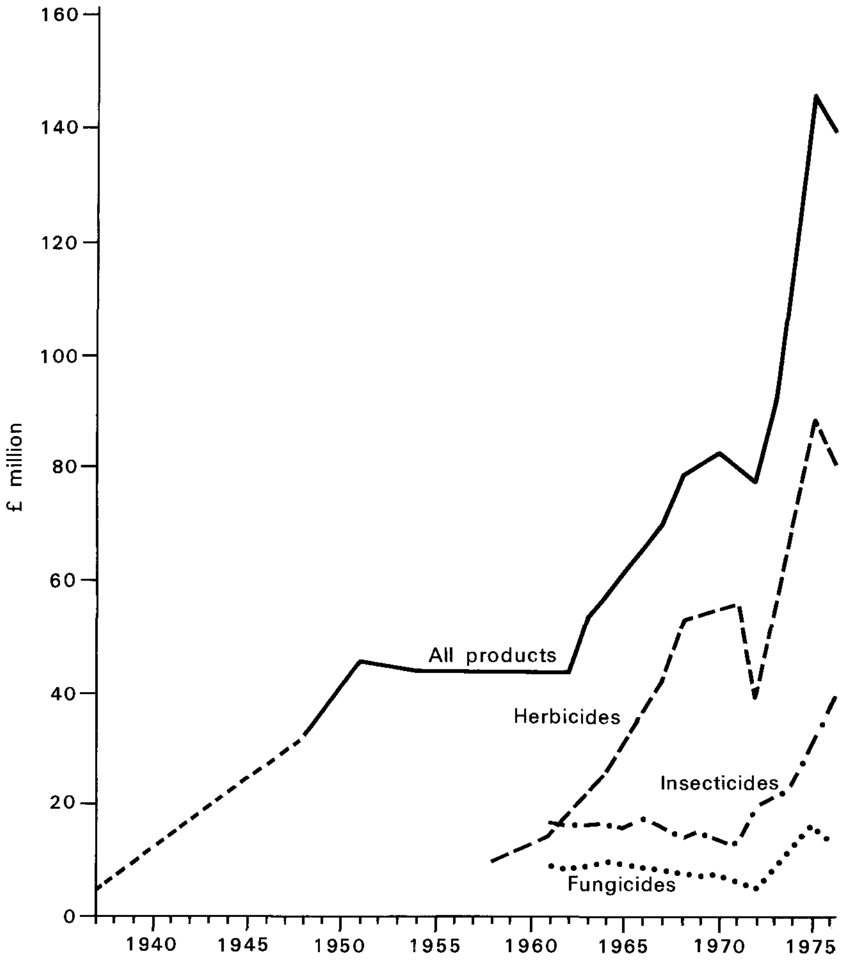
The use of farm chemicals

2.3. In this report, we follow the convention used in the UK to apply the collective term "pesticides" to the diverse group of chemicals used to protect plants and animals from insect pests, and from infectious diseases; they are used also to prevent the growth of weeds. The term thus includes insecticides, acaricides and nematicides (which respectively control insects, mites and some types of worm), fungicides (for the control of diseases caused by moulds), rodenticides (to control rats, mice etc.), molluscicides (which control slugs and snails), herbicides (to control weeds) and growth regulators (for example, to inhibit sprouting or the growth of suckers).

2.4. Although we have been chiefly concerned with the use of pesticides in agriculture, we are well aware that pesticides are used elsewhere—in homes and gardens, in industry and in public health. The non-agricultural uses of pesticides were investigated by the Department of the Environment (DOE) in 1974([12]). It appears that some pesticides (eg dieldrin) are now used in moth-proofing and wood preservation much more than they are in agriculture. The DOE report recommended that the system for ensuring the safety of pesticides used in agriculture and food storage practice should be extended to the general industrial field. It may not be widely appreciated that some industrial uses of such pesticides pose threats to agriculture: we give examples of this in paragraph 6.69.

2.5. Since the Second World War there have been major changes in the pattern of manufacture and use of pesticides. In the UK some 200 active ingredients are now marketed in about 800 approved formulations. Particularly noteworthy is the recent and continuing growth in the use of herbicides. The data we have obtained to illustrate growth in the production and use of pesticides in either financial or tonnage terms are, however, without as much meaning as we would have wished. The British Agrochemicals Association (BAA) has no data on sales before 1974, but has conducted two surveys of the quantities of active ingredients sold, one in 1967 and another for 1975/76; MAFF's pesticide usage surveys run from the mid-1960s. Earlier data can be had from official statistics published by the Department of Industry but these are uncertain because of factors such as changes in the classification of products. The information presented in Figure 2.2 should therefore be regarded as only a rough indication of the trend in the sales of pesticides by UK manufacturers over the period from 1948; figures have been adjusted to 1976 values. It appears that, in 1976, nearly 50 per cent of sales by value were to export and nearly 90 per cent of UK sales were for use in agriculture and horticulture.

Figure 2.2
Sales of Pesticides by UK Manufacturers for Home and Export use - all at 1976 values



2.6. The evidence submitted to us suggested that there is an upward trend in sales of pesticides which reflects increased usage, and not merely increased costs. The BAA told us that agriculture is increasingly dependent on economic and labour-saving means of insect and weed control and the use of pesticides is therefore likely to increase. MAFF confirmed this view; herbicides in particular are likely to become increasingly important in agriculture. More extensive adoption of minimum cultivation methods (see paragraph 4.55) will probably also result in a continued increase of the use of herbicides (in terms of the amounts of active ingredients); the Ministry further considered that there is likely to be an increase of the use of fungicides and growth regulators. The use of insecticides and acaricides, however, might remain at about present levels.

2.7. On the other hand, various technological factors could abate the growth in the use of pesticides. There is room for considerable improvement in the efficiency with which these chemicals are used. For example, it has been estimated that, in some instances, more than one million times as much pesticide may be applied as would be needed to kill the pests([13]). Application technology is at present crude and its efficiency is further reduced by inadequate servicing of machinery; controlled droplet application may bring about a significant improvement of efficiency. We comment further on this matter in Chapter III.

2.8. Another factor that could abate the growth in the amounts of pesticides applied is the development of better forecasting techniques to guide farmers in their decisions on whether and when to spray. Pesticides are expensive and are likely to become more expensive: it is not in farmers' interests that they should be used unnecessarily. In principle, there is a threshold of pest or disease incidence below which spraying with an insecticide or fungicide would give no economic return, but there are difficulties in telling when this threshold has been reached. Much is already done in the UK to provide information for farmers on the need for, and timing of, pesticide application to major crops. Within the MAFF Agricultural Development and Advisory Service (ADAS)* the Plant Disease Intelligence Unit and the Crop Pest Intelligence Unit co-ordinate field data on pest and disease incidence and on meteorological conditions. They prepare national reports, which are put out by the farming press and by BBC farming broadcasts and are widely distributed to ADAS advisers and to the regional organisations of major agrochemical suppliers and contractors. An analogous service operates in Scotland through the Scottish Agricultural Colleges*. There is scope for such services to become considerably more sophisticated.

2.9. Arrangements which aim to ensure that pesticides are used only when necessary to avoid economic damage and that they are applied in the best way and at the best time have been termed "supervised control"([14]). There are, however, other approaches to pest control. Control can be exercised through techniques of husbandry such as crop rotation, the timing of planting and the destruction of crop residues. Varieties of crop plants can be used that are less susceptible to insects or disease. However, breeding to achieve such an effect is necessarily a continuing process, for the infecting agent may also change; a recent development, now under field-scale trials is the sowing not of a single

*The agricultural advisory services are important in the context of our study and we make many references to them, especially ADAS. A description of ADAS and of the corresponding arrangements in Scotland and Northern Ireland is given in Appendix 5.

variety of a cereal crop but of a mixture of cereal varieties, each carrying resistance of different genetic origin to fungal disease.

2.10. An alternative is through what is termed "biological control", the use of the natural enemies of insect pests or weeds to control their numbers. The method has had a few conspicuous successes. The first, in 1888, was against the Cottony Cushion Scale, an organism that had threatened to destroy the citrus industry in California by attacking the trees. The pest was virtually eradicated within a few years by the importation from Australia of a beetle that feeds on the Scale. It is interesting to note that Cottony Cushion Scale reappeared after 50 years of absence because pesticides, introduced after the Second World War, destroyed the beetle. In the UK, natural predators are used with success in glasshouses; a predatory mite is widely used to control populations of the Red Spider Mite.

2.11. The Forestry Commission, in conjunction with other bodies such as the Unit of Invertebrate Virology at Oxford, is evaluating other forms of biological control. Despite the disappointing results obtained in an effort to control the Pine Beauty Moth with the bacterium *Bacillus thuringiensis* the Forestry Commission has reported encouraging results in the control of a fungus damaging to pine trees by introducing a harmless competitive species, and in the control of the pine sawfly, by introducing a virus. The release of sterile males of insect species may also be effective in reducing population growth and so may be the use of insect hormones which sterilise insects or prevent their growth to maturity (a technique recently used successfully to eliminate infestations of "Pharaoh's Ant"* in hospitals([15])). Insect pheromones, (chemicals produced by the insects to attract the opposite sex) can be used also to lure insects to traps. So far pheromones have been used chiefly for trapping insects in order to monitor their numbers and thus to make decisions on the need for pesticide application. Their use in the biological control of insect pests is nevertheless potentially important.

2.12. Unfortunately, the complexity of the ecological relationships that determine the interaction between pests and their hosts make it difficult to select the best method of pest control. Some pest problems have been created or aggravated by the effects of chemicals in killing natural enemies of the pests (see paragraph 2.10). Resistance to pesticides (which we consider further in paragraph 3.26) is an increasing problem, particularly in relation to insect pests and fungal diseases. World-wide public health depends on effective pest control; this emphasises the need for discriminating use of agro-chemicals. Such control may call for programmes of pesticide application and other measures co-ordinated throughout regions. These factors have led to increasing emphasis being placed on the concept of integrated pest management, or "integrated control", a term that connotes the comprehensive assessment of

*Pharaoh's Ant, *Monomorium pharaonsis,* was introduced to the UK in the early 19th century. Infestations are generally found in heated buildings such as bakeries, urban apartment blocks and hospitals. They have been known to penetrate dressed wounds and sterile packs and to transmit pathogenic bacteria.

pest problems based on biological and ecological knowledge and the determination of the best strategies to deal with them. This approach arises from the realisation that pesticides are often not a sufficient remedy by themselves.

2.13. The potential value of alternative methods of control, "biological" or "integrated," was recognised in much of the evidence we received. For example, the BAA told us that, despite many years of research, biological methods have been shown to have only limited application mainly in the controlled environment of glasshouses. On the possible uses of bacteria, viruses and fungi against insects, the Association warned that the dissemination of infective material in the environment is not without danger. In the view of MAFF, the use of biological agents and of chemicals affecting pest behaviour (such as pheromones) might well assume more importance, but such techniques are unlikely to be quantitatively significant before the end of the century: pesticides will long remain the principal means of pest control. We have nevertheless regarded as an important aspect of our study the assessment of the resources devoted to the furthering of such developments.

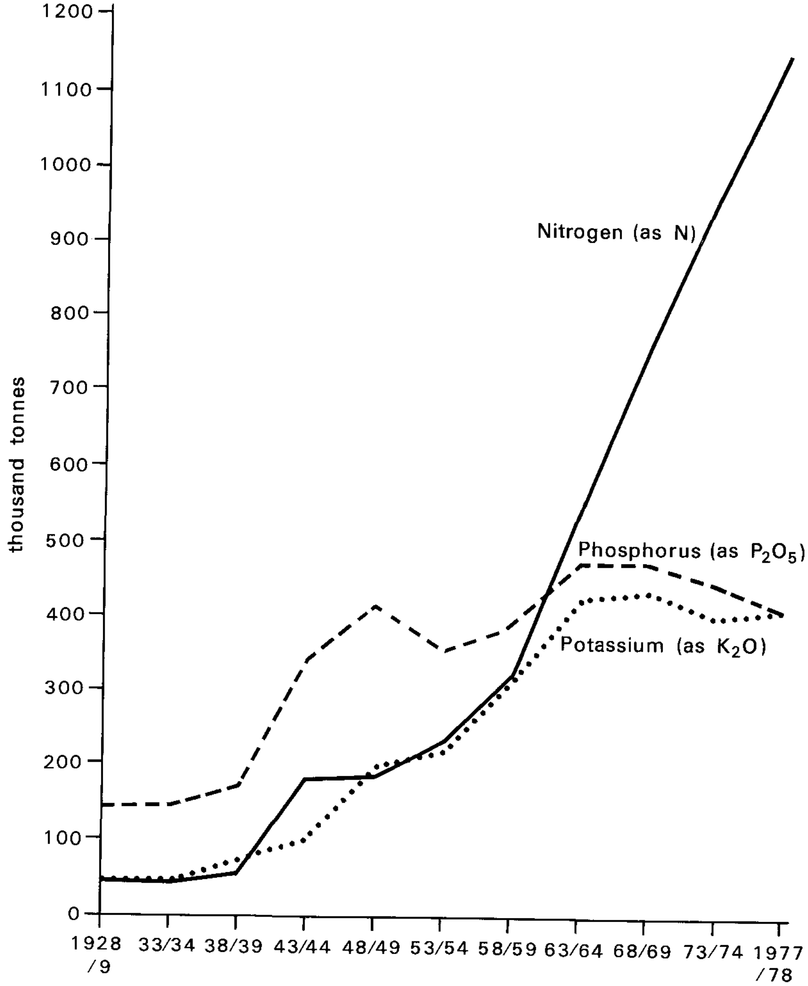
The use of fertilizers

2.14. The chemical elements nitrogen, phosphorus and potassium—(represented by the symbols N, P and K, respectively, in chemical formulae)—are essential for plant growth. Inorganic salts of these elements, or nutrients, may be made up singly in "straight" fertilizers or applied in compound fertilizers that include any two, or all three of them. Since the Second World War, there has been a marked increase in the use of fertilizers, and especially of nitrogenous fertilizers. There is little doubt that this has been a major factor in the remarkable increases of the yields of cereals and other food crops throughout the world. The usage both of potassium and of phosphorus fertilizers appears to have reached a plateau and levelled off; on the other hand, there has been a steady increase in the use of nitrogenous fertilizers with no plateau in sight. (Figure 2.3.)

2.15. Nevertheless, the organizations principally concerned—MAFF, the Fertilizer Manufacturers' Association (FMA) and the National Farmers' Union (NFU)—agree that the rate of growth of usage of nitrogenous fertilizers is likely soon to decrease. Their view is that levels of fertilizer application on arable crops are already close to that optimum which yields the best economic return and that the main area of potential increase is in the application of nitrogenous fertilizer on grass where current usage appears to be far below the optimum. It is mainly intensive dairy enterprises which can effectively utilise the high yields of grass that can be obtained from very high rates of nitrogenous fertilizer application to grassland, and in 1976 only 12 per cent of grassland received such very large dressings of fertilizer (in excess of 250kg of N/ha). Future rates of application must depend on future investment in livestock, which in turn depends on uncertain factors, including economic circumstances and long-term trends in ECC agricultural policy. About 1·2m tonnes of nitrogen in the form of nitrogenous fertilizer is now applied annually to crops and grass (Table 2.2 indicates roughly how this is apportioned) but

MAFF quoted an estimate (derived from commercial sources) that the use of nitrogenous fertilizers could increase by a further 50 per cent by year 2000—that is, by an extra 0·6m tonnes of nitrogen per annum in England and Wales, most of the increase going to grassland. This would correspond to an annual growth rate of nearly 2 per cent.

Figure 2.3
Trends in Fertilizer Usage in the UK



SOURCE: Fertilizer Manufacturers' Association

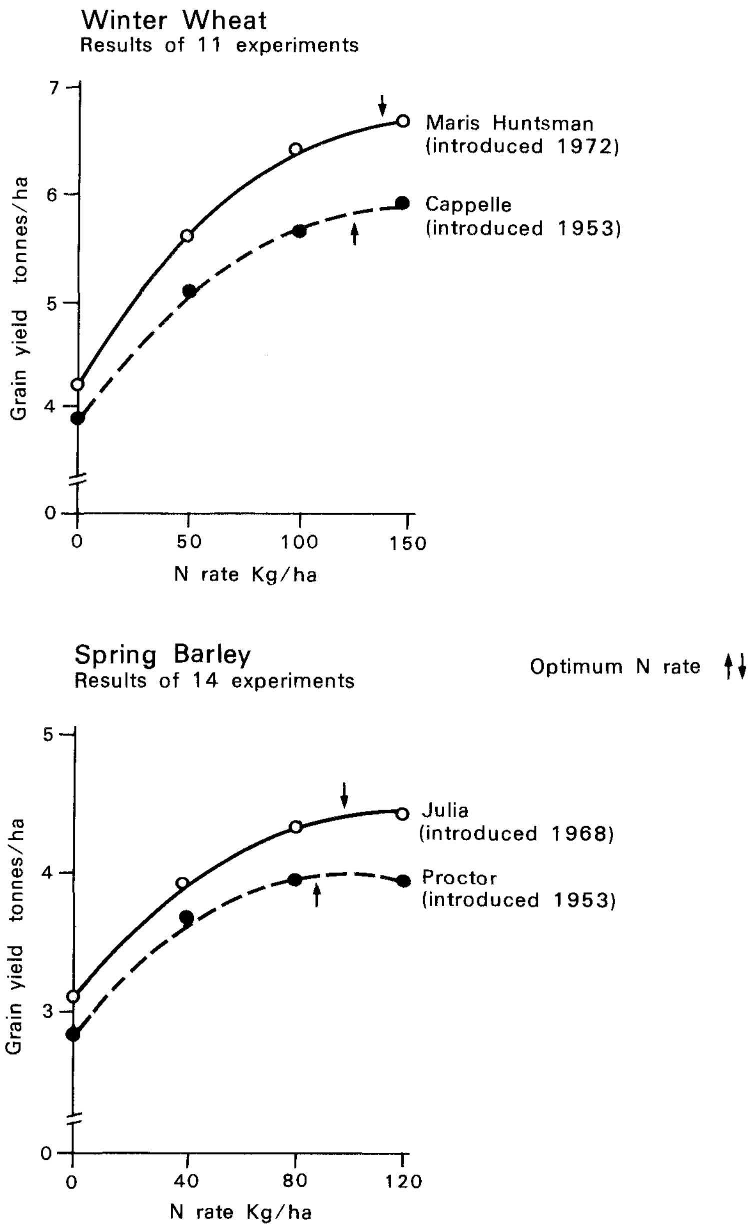
TABLE 2.2

	Area (as % of all crops and Grass)	Amount of N applied (as % of total N fertilizer)
Cereals	30	28
Other arable crops	10	7
Temporary grass	20	30
Permanent grass	40	35

2.16. It is uncertain how far usage of nitrogenous fertilizers on arable crops may increase with the introduction of new crop varieties able to respond to higher levels of nutrient supply. The dependence of the yield of cereal varieties on the use of fertilizers has certainly been significant in the recent past (see Figure 2.4) although MAFF told us that much of the increased usage would have been necessary even with the older crop varieties. The Ministry therefore believes that the rate of increase of fertilizer usage on arable crops will be much less than the average of the past thirty years even if policies of self-sufficiency in these crops were to be adopted. The MAFF view differed somewhat from that expressed by the Agricultural Research Council's Plant Breeding Institute (PBI), which gave us a tentative estimate that nitrogen usage on cereals in twenty years' time might be about one and a half times that at present. (Usage has in fact about doubled in the last twenty years.) Such an increase on cereals, which comprise about 75 per cent of the arable crop, would itself imply an additional 0·15m tonnes or so of nitrogen per annum by the year 2000. In its evidence, MAFF referred to the so called "maximum-yield" systems which, if generally adopted, might lead to greatly increased nitrogen applications on certain crops. We discuss this matter in paragraphs 4.56–4.58. It is only proper to acknowledge that, when coupled with other technological developments and especially the better utilisation of fertilizers, "maximum-yield" systems need not necessarily involve larger applications of fertilizers.

2.17. The more effective use of conventional fertilizers may eventually be matched by other and more speculative possibilities. One is the incorporation of nitrogen-fixing genes into the cells of plants, such as cereals and grasses. Some bacteria can "fix" nitrogen from the air, i.e., they can transform the nitrogen into forms in which it can be taken up by plants. In leguminous plants such as clover, bacteria with this property live within the nodules in the root system, in symbiotic relationship with the plant; the plant supports the bacteria which in turn fix the nitrogen required for the plant's growth. In the past few years techniques have been developed for the transfer of nitrogen fixation genes from one species of bacteria to another. This raises the possibility that, by comparable techniques, the ability to fix nitrogen could be introduced into plant cells; crops such as cereals might then fix some of the nitrogen they need for growth. Although such developments may in due course be realised, our judgement is that they will not have much impact on fertilizer requirements in the UK before the end of the century.

Figure 2.4
Response of Cereals to Fertilizer Nitrogen



SOURCE: J.D. Whitear in Fison's 'Ag Tec' Autumn 1976

Changes in livestock farming

2.18. There have also been important developments in the past few decades in the techniques of animal husbandry. In dairy farming, for example, the average annual milk yield per cow is now 4,452 litres compared with 2,730 litres just after the Second World War. Through developments in feeding systems and milking machinery, one man can now keep 100 cows milked. Through fertilizer use and by means of other techniques, the amount of grazing land needed to support one cow is now 0·6 hectares compared with one hectare just after the Second World War. If more fertilizers were used on grassland (paragraph 2.15) this area could well fall to 0·4 hectares. There has also been a marked shift from the bedding of dairy herds on straw to their housing in cubicles, with the result that there is a liquid slurry to be disposed of: this gives rise to the risk of pollution from leakage or overflow, from the run-off of slurry, and of smell from that slurry spread on land or stored. To a lesser extent, similar trends are apparent in the beef cattle industry. An associated pollution risk arises in the production of the silage that is increasingly used for winter feed; silage effluent is a notorious cause of the pollution of water courses.

Plate 2.1. Pigs housed indoors under environmentally controlled conditions.

Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

2.19. Similar pollution problems associated with waste disposal are apparent in the poultry and pig industries; these have changed towards being very

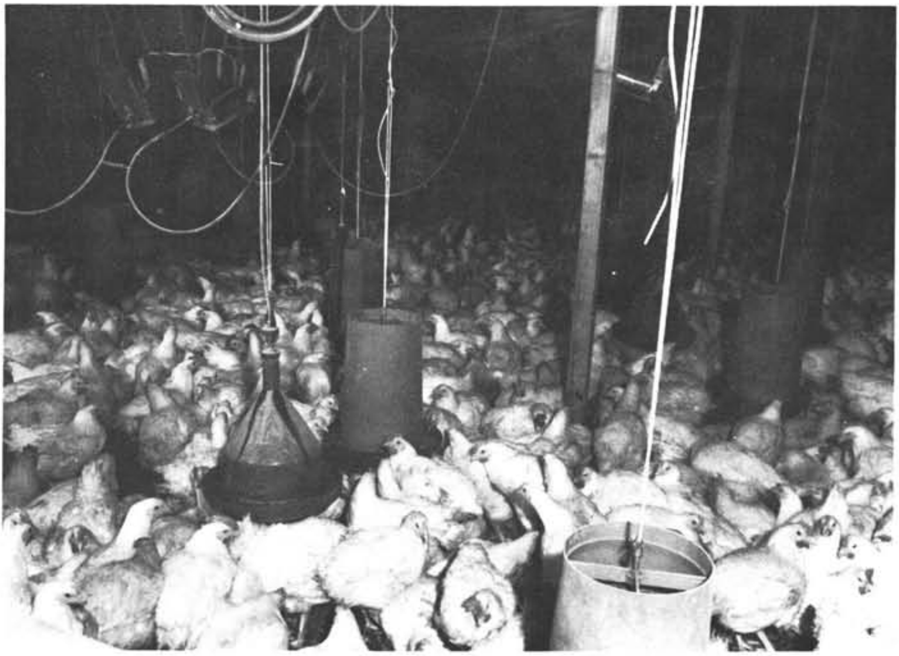


Plate 2.2 Interior of a deep litter house for raising broiler chickens.
Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

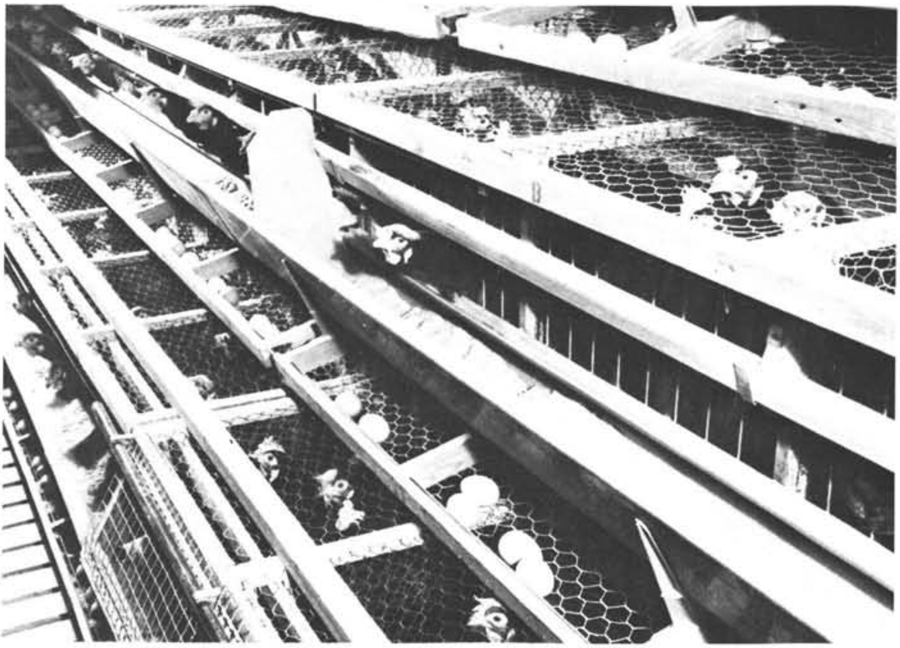
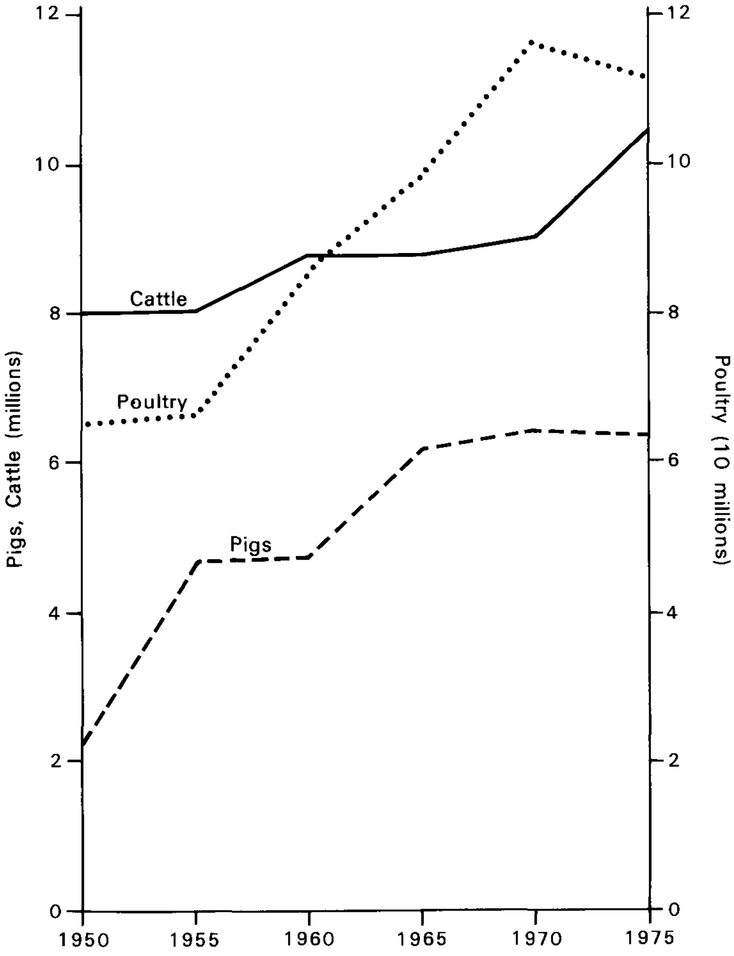


Plate 2.3. Laying hens housed in battery cages.
Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

large operations. Chickens and pigs are now mostly housed indoors under environmentally controlled conditions (see Plates 2.1, 2.2 and 2.3) and with automatic arrangements for feeding and for the removal of excreta; pollution risks arise from the storage, treatment and disposal of these excreta. Odour problems from poultry arise particularly when the excreta are heat-dried before being moved from a unit. Pig and cattle manure, now handled mainly as slurry, also creates disposal problems. Sheep seem to have resisted the trend to intensive husbandry; thus at present any pollution from sheep husbandry arises from the disposal of the chemical used against sheep scab.

Figure 2.5
Total Livestock on Agricultural Holdings
in England and Wales



SOURCE: ARC

2.20. The numbers of livestock kept on agricultural holdings have increased steadily since 1950 as shown in Figure 2.5. The size distribution of livestock enterprises is shown in Table 2.3; in all sectors, there is an evident trend towards larger herds and flocks, and a consequent decrease in the number of smaller enterprises.

TABLE 2.3

The Distribution of Herd/Flock Size in England and Wales

	1960	*1965*	*1970*	*1975*
1. No. of dairy herds, by size of herd				
Over 200 head	65	111	340	671
100–199 ,,	673	1,220	2,366	3,886
70–99 ,,	2,142	2,707	4,825	6,413
Under 70 ,,	137,228	110,459	77,360	51,763
2. No. of beef herds, by size of herd				
Over 200 head	12	31	54	138
100–199 ,,	121	161	352	798
70–99 ,,	259	371	642	1,271
Under 70 ,,	63,657	60,459	54,064	57,129
3. No. of pig herds, by size of herd				
Over 5,000 head }	130	374	11	45
1,000–4,999 ,, }			714	1,233
Under 1,000 ,,	111,534	94,265	59,128	32,013
4. No. of poultry flocks producing eggs for eating, by size of flock				
Over 20,000 head	186	103	263	351
10,000–19,999 ,,	437	304	494	503
Under 10,000 ,,	135,949	157,696	90,421	58,020
5. No. of broiler flocks by size of flock				
Over 1,000,000 head }	44	47	38	8
500,000–999,999 ,, }			6	9
250,000–499,999 ,, }			8	7
100,000–249,999 ,, }			39	63
50,000–99,999 ,,	86	59	91	117
Under 50,000 ,,	3,062	2,694	1,742	1,314

Source: Agricultural Research Council/MAFF (1976).

2.21. The number of large livestock enterprises operating on holdings of relatively small area is also generally increasing, as shown in Table 2.4.

TABLE 2·4

Numbers of large enterprises being kept on small areas of land (England and Wales)

	1960	*1970*	*1974*
Number of dairy herds of 100 head or more on holdings of less than 60 ha (150 acres).	12	128	342
Numbers of beef herds of 100 head or more on holdings of less than 60 ha (150 acres).	6	22	58
Number of pig herds of 1,000 head or more on holdings of less than 8 ha (20 acres).	0	126	284
Numbers of flocks of poultry (layers) of over 5,000 head on holdings of less than 2 ha (5 acres).	278	466	405
Number of broiler flocks of over 250,000 head on holdings of less than 20 ha (50 acres).	7	11	12

Source: Agricultural Research Council (1976).

2.22. Animal manures contain nutrients that can replace some of the inorganic fertilizers that would otherwise be needed. The relative proportions of the important nutrient elements in manures rarely match the requirements of a particular crop exactly. An excess of any such element could harm growing plants or grazing animals and the maximum rate of application is therefore set by the limiting element. We discuss this more fully in paragraphs 5.15–5.17. Table 2.5 gives approximate values for the maximum number of livestock whose excreta could be applied to 1 hectare of land bearing different kinds of crop without exceeding the maximum crop requirement for any of the important nutrient elements. Traditionally, livestock manure was returned to the land to maintain soil fertility. When livestock are concentrated, however, the available land may be insufficient for satisfactory disposal. Manures or slurries must then either be disposed of elsewhere or deposited at excessive rates on the land available. The point is illustrated by comparing Tables 2.4 and 2.5. For example, for pig holdings having more than 1,000 head on less than 8 hectares the stocking density exceeds 125 pigs/hectare which is substantially above those derived from Table 2.5 (17–80 pigs/hectare).

TABLE 2.5

Maximum numbers of housed livestock whose manure can be applied to 1 hectare of crop without exceeding the maximum crop requirement for the important nutrient elements.

	Dairy cattle housed for 6 months	*Pigs housed for 12 months*	*Poultry housed for 12 months*
Grass for fodder	11·2	80	1,160
Grazed grass	4·5	35	590
Cereals	2·3	17	300
Other arable crops	7·5	40	580

Source: MAFF Short Term Leaflet 185.

2.23. Increasing specialisation has shaped and will shape the geographical pattern of agriculture in the UK. Figures 2.6–2.11 show clearly the changes over the past 40 years in the distribution and intensity of cereal, pig and poultry production*. The concentration of intensive piggeries in areas such as Humberside, and the preoccupation of East Anglia with cereal crops, are explicable in economic terms but may raise pollution problems that were unforeseen. More dramatic consequences could flow from apparently small changes in agricultural policy: for example, many square miles of upland Britain could become forests if there were shifts of policy on (or prices for) beef and lamb.

*Figures 2.6–7 show the total area of wheat, barley and oats expressed as a percentage of agricultural land. Figures 2.8–11 show the numbers of pigs and fowls per 1,000 acres (400 hectares) of agricultural land. There are slight differences due to changes in county boundaries during the time spanned.

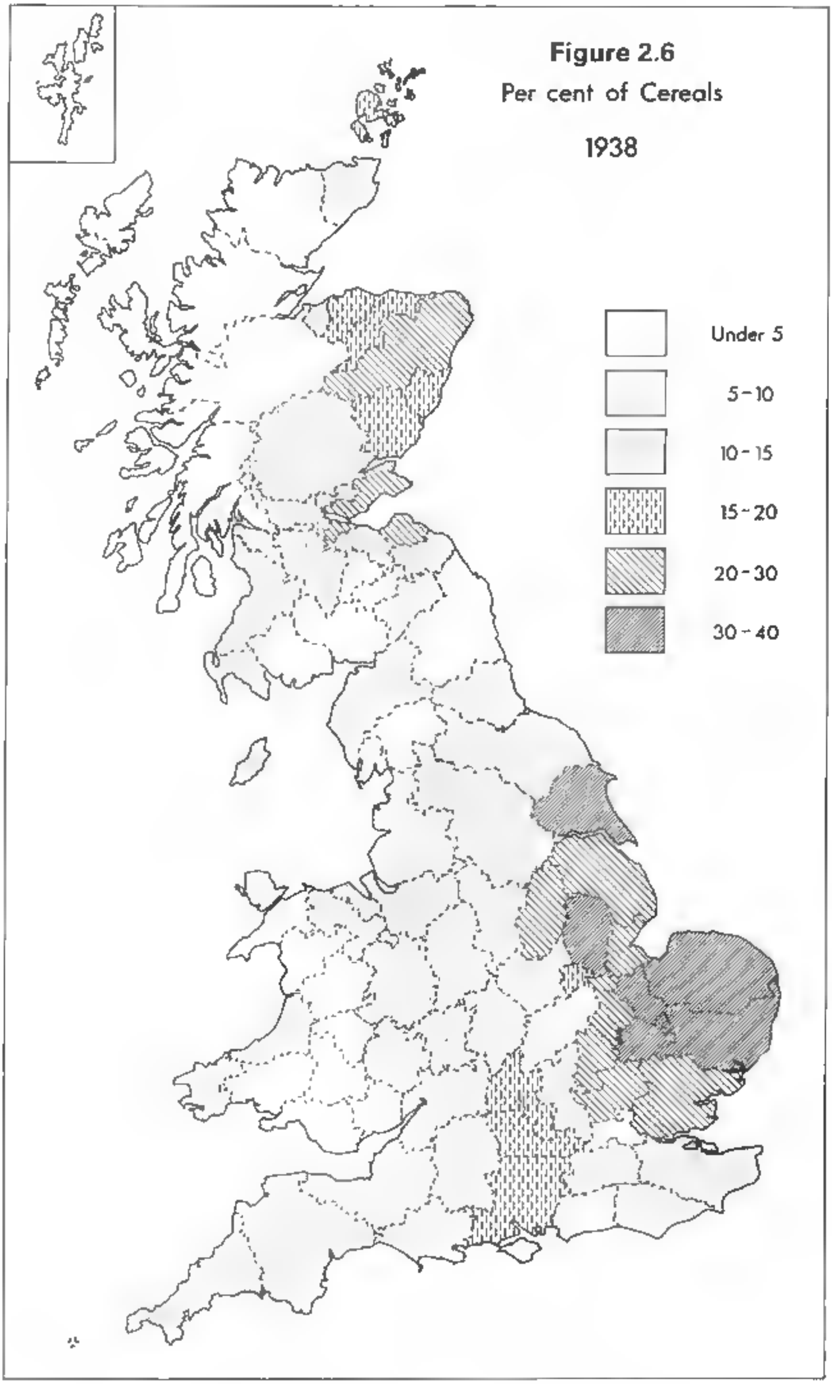


Figure 2.6
Per cent of Cereals
1938

Total of Wheat Barley and Oats as a percentage of Agricultural Land

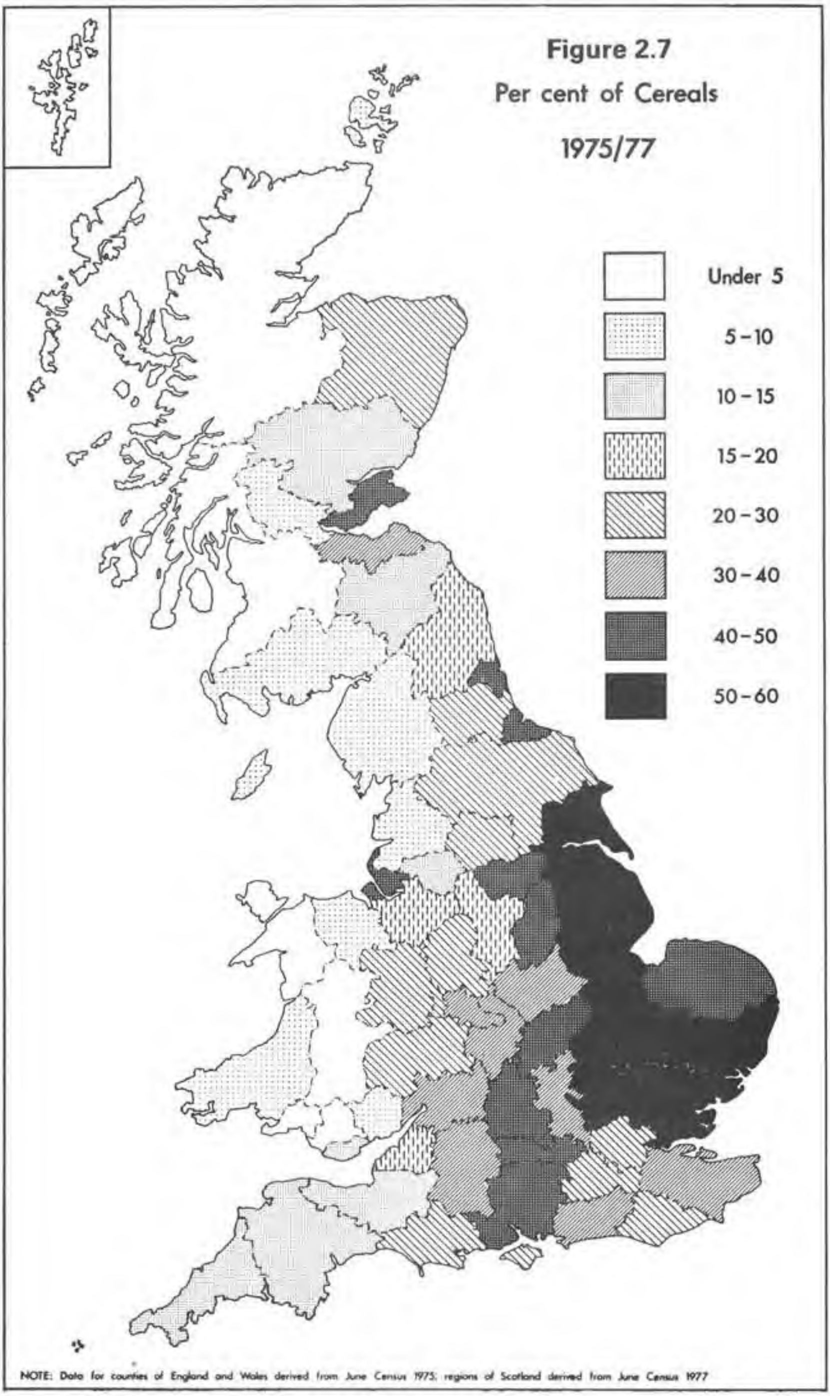
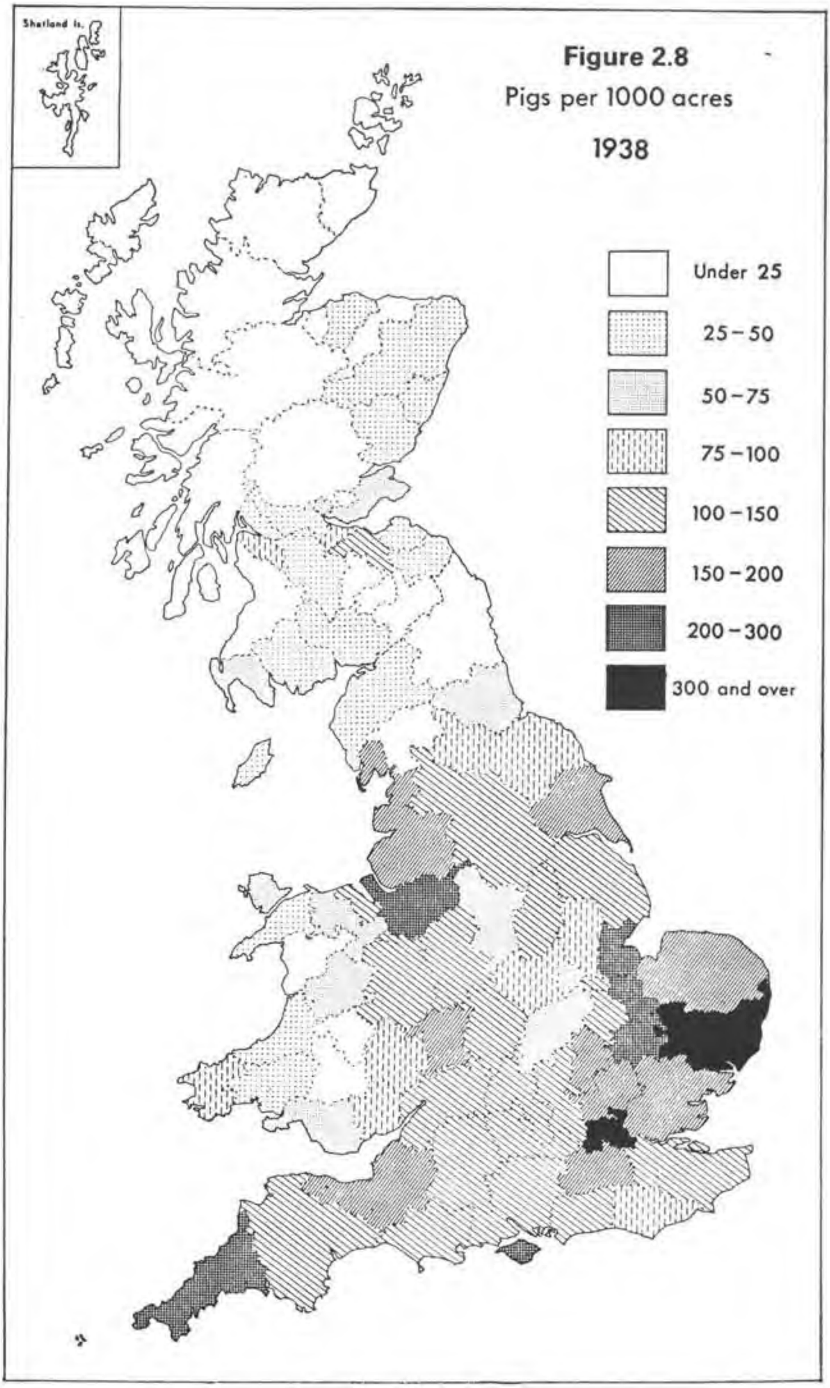


Figure 2.7
Per cent of Cereals
1975/77

NOTE: Data for counties of England and Wales derived from June Census 1975; regions of Scotland derived from June Census 1977


Shetland Is.
Figure 2.8
Pigs per 1000 acres
1938
Under 25
25 – 50
50 – 75
75 – 100
100 – 150
150 – 200
200 – 300
300 and over

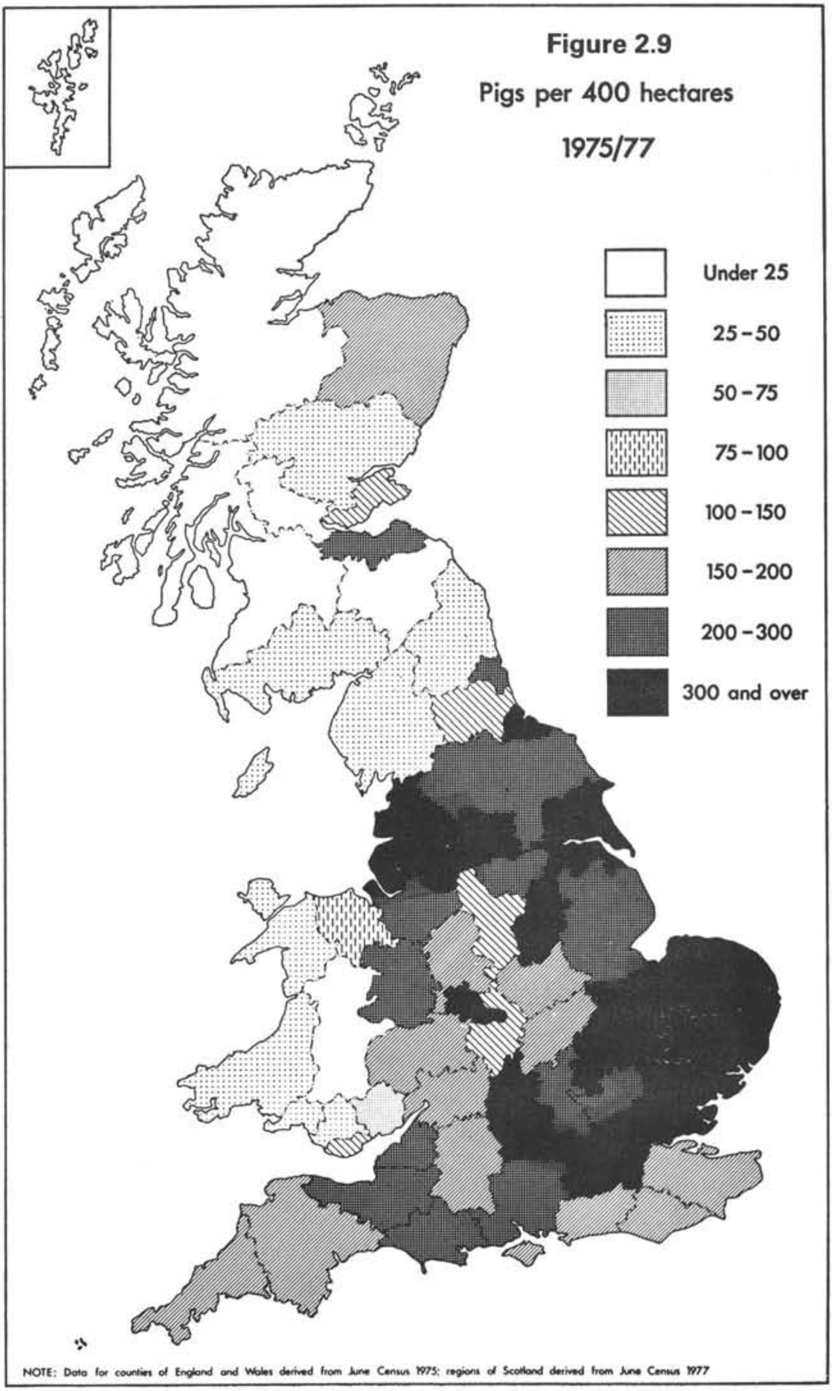
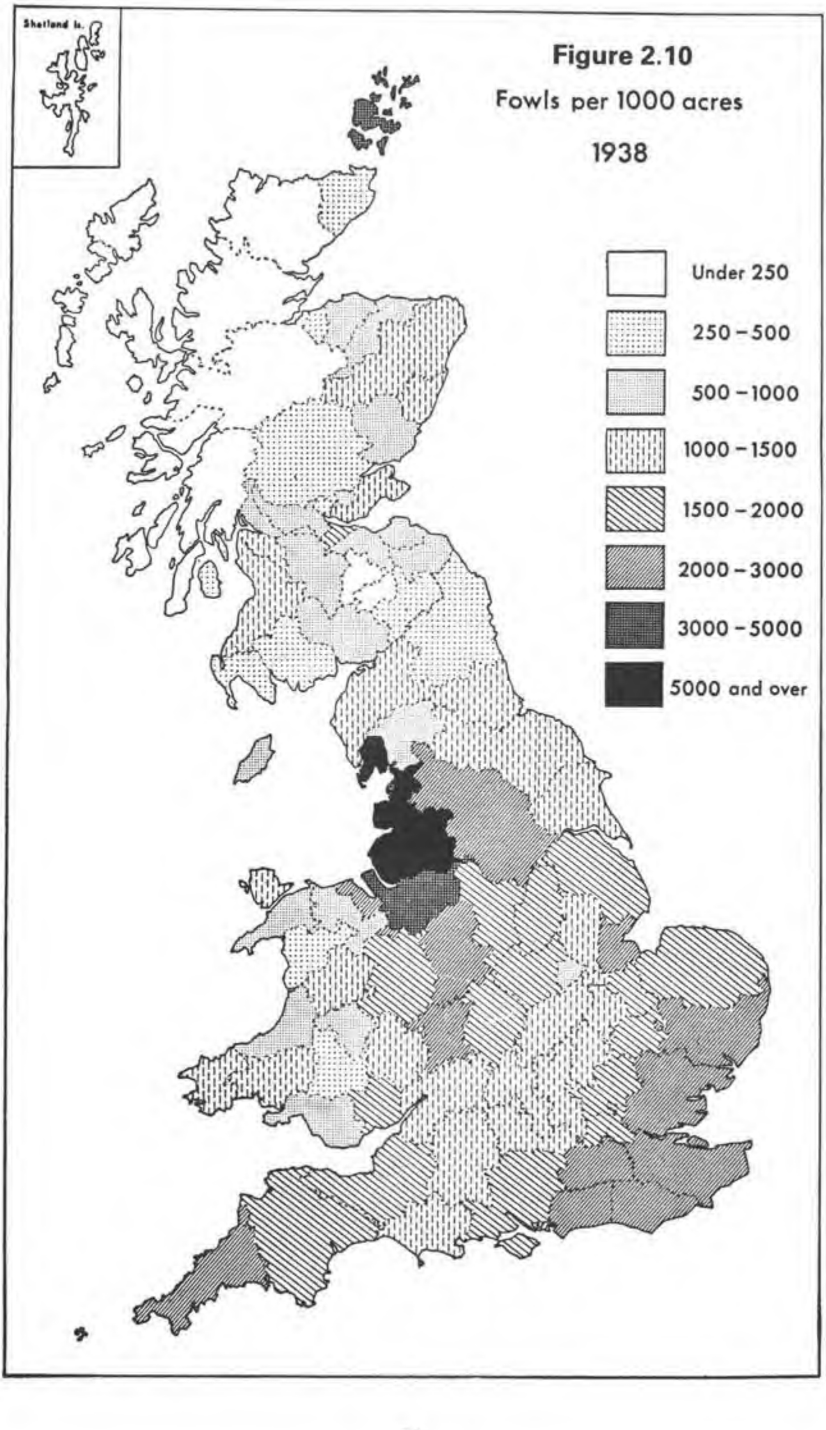


Figure 2.9
Pigs per 400 hectares
1975/77
Under 25
25 – 50
50 – 75
75 – 100
100 – 150
150 – 200
200 – 300
300 and over
NOTE: Data for counties of England and Wales derived from June Census 1975; regions of Scotland derived from June Census 1977


Shetland Is.
Figure 2.10
Fowls per 1000 acres
1938
Under 250
250 – 500
500 – 1000
1000 – 1500
1500 – 2000
2000 – 3000
3000 – 5000
5000 and over

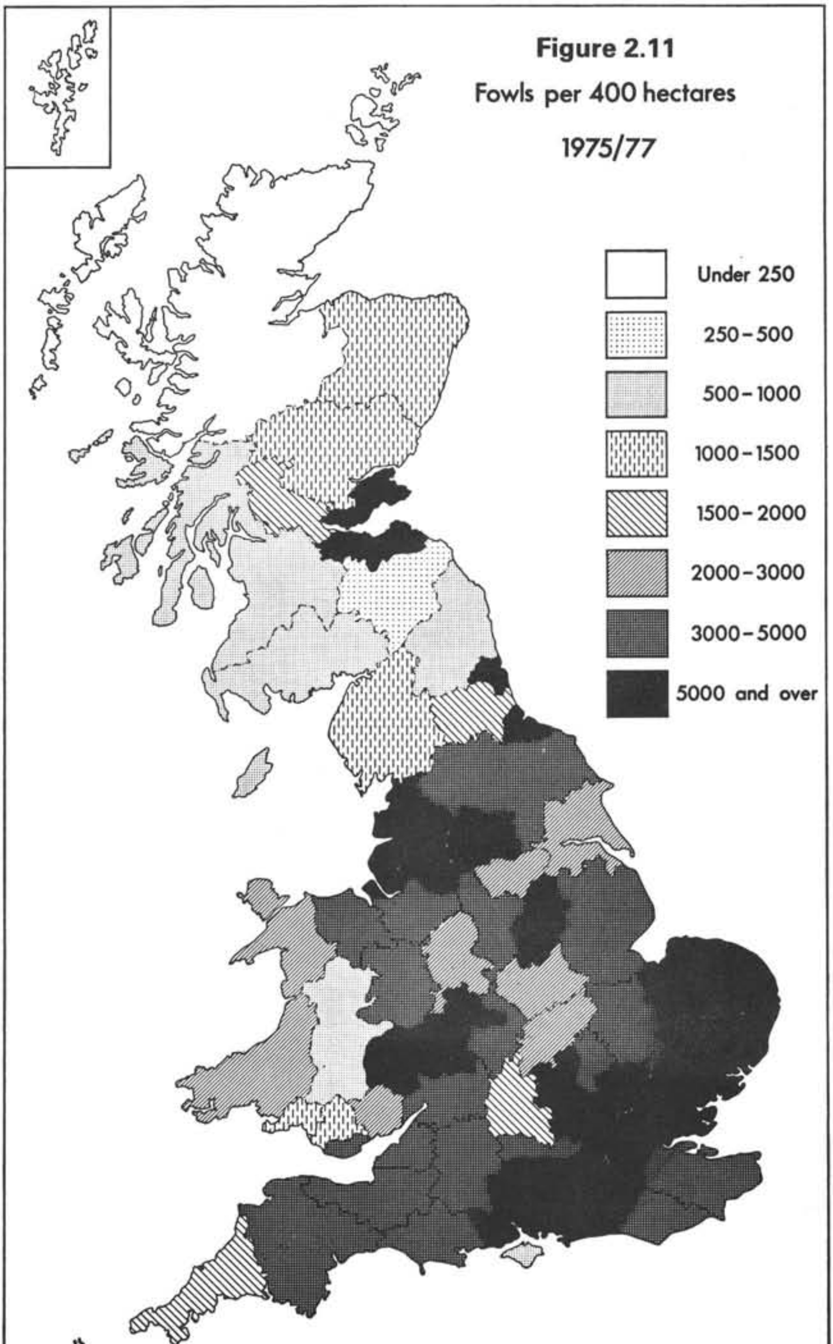


Figure 2.11
Fowls per 400 hectares
1975/77

NOTE: Data for counties of England and Wales derived from June Census 1975; regions of Scotland derived from June Census 1977

The loss of agricultural land

2.24. In an industrialised country as small and as densely populated as the UK, competition for land is inevitable. Land is the essential resource for agriculture and forestry. It is needed also for many other purposes including housing, transport, industry, mineral extraction, reservoirs, wildlife conservation and recreation. Such demands have led to a continuing loss of agricultural land. The main concern is that some of those losses, particularly the losses to urban development, are irreversible. The loss of farmland is relevant to our present study primarily to the extent that its continuance might lead to an intensification of agricultural practices beyond what might otherwise occur and thus increase the risks of pollution. We present in Tables 2.6 and 2.7 some data about land use and the quality of agricultural land in the UK.

TABLE 2.6.
Estimates of land use in the UK 1976

Land use	Area (million hectares)	% Area
Crops and fallow	4·80	19·9
Temporary grass	2·31	9·6
Permanent grass	4·95	20·5
Rough grazing	6·77	28·1
Other land	0·31	1·3
Total agriculture	19·14	79·4
Urban	1·85	7·7
Forestry and woodland	1·78	7·4
Miscellaneous	1·33	5·5
Total land	24·10	100·0
Inland water	0·37	

TABLE 2.7
Estimates of agricultural land in the UK by grade (see below) 1976

Grade	Area (million hectares)	% Area
1	0·35	1·8
2	1·88	9·8
3	6·97	36·4
4	3·49	18·2
5	6·45	33·7
Total	19·14	99·9 (not exact due to rounding)

Source: Agriculture EDC report on land use([16]). The figures have been rounded.

The grades referred to in Table 2.7 are those used in the MAFF classification of the quality of agricultural land. Grades 1 and 2 include the best farming land in the country; it can be used to grow a wide range of crops with high yields. The potential of Grade 3 land is to some extent limited by soil, relief (gradient, altitude and the like) and climate; the choice of crops and the yields obtainable are restricted. Grade 4 land has more severe limitations and for the most part is capable of growing only crops (hay for example) for the winter feeding of stock. Grade 5 land is used largely for rough grazing. A somewhat different classification system is used in Scotland but the equivalent grades are used in the table. Plainly the quality of the land is important in trying to assess the consequences of land losses either for pollution or more generally.

2.25. There is considerable uncertainty about the quality of agricultural land that has been transferred to urban development in the past. We share the concern that has been expressed by other bodies on this point and welcome the steps that are being taken to improve the statistics of land losses and to show losses of agricultural land by grades. One study([16]) has suggested that over the period 1931 to 1971 there was, in England and Wales, no disproportionate loss of land to urban development from land of the top three grades. In Scotland, however, where there is a relatively small proportion of high quality land, the loss of such land appears to have been disproportionately high. Figures supplied by the Department of Agriculture and Fisheries for Scotland (DAFS) show that while less than 3 per cent of land in Scotland is in the equivalent of grades 1 and 2, some 26 per cent of land taken for urban development in a three year period from 1973 was from these grades.

2.26. In England and Wales since the Second World War, the annual net loss of agricultural land to urban development is estimated to have ranged between 13,000 and 20,000 hectares. Comparable figures for Scotland did not become available until 1960, since when annual losses to urban use have been estimated as between 2,000 and 3,000 hectares. Probable future trends in the loss of agricultural land were considered by a Working Group of the Agriculture Economic Development Committee (EDC) in 1977([17]) when it was estimated that the average rate of transfer of farmland to urban development in the UK during the succeeding ten years was likely to be rather less than 20,000 hectares per annum. Assuming this figure, we attempt below a rough assessment of the possible implications for pollution of land loss up to the year 2000.

2.27. If a rate of loss to urban development of 20,000 hectares per annum were to continue from the present until year 2000, the proportion of agricultural land lost by that time would be about 2 per cent. This calculation includes rough grazing land which is unlikely to be taken for urban use. If such land is excluded, the proportion of crop and grass land taken by year 2000 would be about 3·4 per cent. This figure does not necessarily provide a measure of the likely effect of such a loss on the productive capacity of agriculture since it takes no account of differences in the quality of the land concerned. Generally, the qualities that make land highly productive in agricultural use (for example, that the land is flat and well-drained) also make it attractive for urban development. Such land is essentially land in Grades 1–3 and if this were to sustain the whole of the projected loss to urban development then the loss of land in these grades would be about 4·6 per cent by year 2000. If this loss were distributed proportionally within Grades 1, 2 and 3 (which would imply that one quarter of the projected loss is sustained in land of Grades 1 and 2), the corresponding loss in productive capacity would be less than 4·6 per cent. We consider this estimate of 4·6 per cent to be a reasonable guide to the possible loss of high quality land to urban development by the end of the century, mainly because of existing policies for safeguarding agricultural land (especially land of high quality) and the likelihood that these policies will be strengthened in response to the concern about this matter that has been expressed by several bodies.

2.28. The added pollution risks that would arise from an intensification of agriculture which might be supposed to take place to make good this 4·6 per cent loss spread over 20 years are very small, at least in comparison with other changes that may occur. The future of agricultural output and productivity is in any case uncertain. Both may be limited by shortages of energy, or rising prices thereof. The Agriculture EDC noted that over the 10 years to 1974/75 agricultural net product (at constant prices) grew on average at the rate of 2½ per cent–3 per cent per year and expressed the view that overall productivity is unlikely to slow down if the recommendations of other EDC working groups are put into effect. We note that the 1975 White Paper "Food From Our Own Resources" projected a growth rate of 2½ per cent per year. The 1979 White Paper "Farming and the Nation", suggests that, on the basis of alternative hypothetical price assumptions, net product in 1983 might be some 10–20 per cent higher in real terms. These projections apply only to the medium term, but if comparable rates of growth were to be sustained to the year 2000 this would imply an increase approaching 70 per cent. Other studies on the other hand suggest that the rate of growth in productivity is declining: that the limits of yield are being approached and that the rate of growth of productivity over the period to the year 2000 may be no more than about 1¾ per cent; even so, this implies an aggregate increase of over 30 per cent.

2.29. We recognise that the loss of land from agriculture is a contentious issue on which strongly opposed opinions are held. In an uncertain world, most of us would accept the argument that it would be wise to preserve, more tenaciously than hitherto, the basic resource on which future food supply may depend. Our present concern, however, is with pollution. On the calculations given above, we conclude that the intensification of agricultural practices that might be necessitated by land loss by year 2000 is negligible. Hence, the pollution hazard posed by such land loss is also negligible.

Fish farming

2.30. The controlled rearing of freshwater fish, for food as well as for the restocking of waterways and lakes, is a new and growing element in the pattern of British agriculture. We have been told that there are now about 400 fish farms in the UK, most producing rainbow trout for the table. MAFF estimated that about 4,000 tonnes of trout are now being produced each year and, subject to the availability of suitable sites and the effectiveness of marketing, this might increase five-fold over the next decade. The National Water Council

(NWC) expressed concern about the growth of the industry on three counts. In the first place, trout farms require a large through flow of water and are invariably sited where abstractions can be made from a river (see Plate 2.4). The flow of water through the fish ponds must be maintained even when the river is low and so it is possible in extreme conditions for a river to run dry between the points of abstraction and discharge. We were told of several cases where this had happened, albeit in the exceptionally dry summer of 1976. Such happenings can be avoided by relating the size, design and site of a proposed fish farm to the probable minimum flow of the river from which water is to be abstracted. Secondly, the quality of water emerging from a fish farm may have deteriorated as the result of the addition of fish excreta, waste food and the residues of chemicals used to protect against fish disease. This will not only concern the water authorities but would also affect the operation of any fish farms further downstream: fish farms are peculiarly vulnerable to water pollution. Thirdly, disease can spread rapidly through colonies of farmed fish and might possibly spread to the wild fish population.

Plate 2.4. A fish farm on a tributary of the River Hull near Great Driffield.
Photograph by courtesy of Wansford Trout Farms.

2.31. With regard to pollution and spread of disease from fish farms, we were told by DOE that a preliminary survey co-ordinated by the Water Research Centre (WRC) showed that serious pollution was unlikely. However, it was not possible to say that no problem existed because there was insufficient information about the spread of disease between farms and to wild fish populations and about the effects of protective chemicals used in fish farms. This is acknowledged by MAFF, who told us that a review of fish disease policy is now in progress. We comment on fish farming in relation to planning matters in paragraph 7.15.

Organic farming

2.32. We received evidence from some bodies suggesting that if there were a general change to organic farming (that is, farming without recourse to synthetic fertilizers and agricultural chemicals), many of the pollution hazards associated with conventional modern farming practices would be eliminated. Although there are undoubted benefits in pollution terms, whether they could be realized would depend upon whether the widespread adoption of organic farming would allow food supplies to be maintained. We discovered that organic farming systems fall broadly into two types. The first, which MAFF called "low input/low output", does not attempt to compete with conventional methods in terms of yield. Supplies of plant nutrient come mainly from soil reserves, from the rotation of leguminous crops and from the return of all plant and animal wastes produced on the farm. The second type, "high input/high output", depends on bringing plant nutrients onto the farm either directly, as animal manures from other farms or "natural" inorganic fertilizers, or indirectly, as animal feed which results in animal manures. Although this second type of farm can produce local yields comparable with conventional farms, there is insufficient animal manure and other organic waste in the UK to sustain such systems on a large enough scale to feed the population. Neither type of farm will use synthetic pesticides; to some extent the traditional pattern of crop rotation on such farms reduces the need for some pesticides, notably herbicides, but inevitably the buyers of organically grown produce must accept more pest damage or be prepared to pay a high premium for undamaged produce. We concluded that although organic farming caters for those who are prepared to pay more for something which they consider special, it will not become a large part of the agricultural scene and that its influence on the issues discussed in the Report will remain negligible.

Long-term developments in agriculture

2.33. We have briefly discussed likely future trends in some aspects of modern agriculture. The projections made implicitly assume the continuation of the present general pattern of agriculture; they amount, in effect, to an extrapolation of present practices, taking some account of possible developments in techniques where their potential can be seen with reasonable clarity. We considered that we should attempt to go further than this in enquiring about the future. It seemed possible that, within the time scale of our study, various factors could bring about more radical changes in the shape of agriculture in the UK which might have significant pollution implications. We had in mind factors such as a possible future requirement for a much higher level of self-sufficiency in temperate foodstuffs, as a result of changes in world food supply and demand; the impact of substantial future increases in energy costs; the possibility of significant changes in dietary habits; the possibility that developments within the European Community might lead to some rationalisation of agricultural activity within Member States; the possibility of adverse climatic changes; the development of resistance to insecticides (see paragraph 3.26); or the extent to which agricultural productivity would be expected to continue to increase. Clearly, any attempt to assess matters of this kind is beset with major difficulties and uncertainties and it might be thought that these are so great as to render the exercise valueless. It appeared to us, however, that some consideration should be given to speculative, long-term developments; to the effects and inter-play of possible, even though improbable events. Such thinking might indeed prove too conjectural to be of present value but it might disclose factors that should influence current policies.

2.34. We were disturbed to find that systematic studies of this kind were apparently not already undertaken periodically by MAFF as a regular feature of its work. To meet our request, the Ministry arranged a special study on the theme of agriculture in 2000 AD. The resulting analysis of past and probable future trends was most helpful to our enquiry; indeed, where it seemed relevant to our purposes, we have incorporated material from this analysis in earlier sections of this Chapter and elsewhere in our report. Moreover, we think that the full analysis, together with a subsidiary study to which we refer further below, will be of wide general interest and we have therefore reproduced them in Appendix 6.

2.35. In its first analysis, MAFF sought to forecast the likely future developments in agriculture, though stressing the many unknowns that make firm prediction impossible. The Ministry expressed the view that if many factors turn out favourable, farms in the UK will be operating at the end of the century in a supply situation broadly similar to that of today, but that it would be prudent to recognise that they might be under pressure to produce a much higher proportion of our total needs for food. The forecast amounts, in effect, to an elaboration of the trends that we have already noted towards greater specialisation and intensification in agricultural practices. It was an awareness of the changes that have already occurred in this direction that led us to think that a study of the associated pollution risks would be desirable. The expected continuation of these trends appeared to us to indicate that we were correct in this view. We were, however, interested not only in the most likely future but in the question of whether less probable developments that might be dictated by changing circumstances might have significantly different implications in pollution terms. MAFF accordingly undertook a second analysis in which the possible effects of factors of the kind outlined in paragraph 2.33 were further considered.

2.36. It cannot be said that the analysis revealed any matters that seemed likely materially to affect our findings. As would be expected, a possible future requirement for a much higher level of self-sufficiency in temperate foodstuffs would lead to changes in the balance of different agricultural activities, with probable expansion of areas used for crops and perhaps a substantial increase in fertilizer usage particularly on grass, to permit higher stocking densities of grazing animals. However, constraints might well be set on changes by increasing energy costs. We noted the possibility that this factor might affect the trend towards specialisation and might lead to a shift towards mixed farming systems in order to reduce the energy costs associated with the transport of animal feedstuff. Another aspect of increasing energy costs that would be important from the pollution viewpoint is the incentive to provide for the more efficient use of animal wastes to reduce the need for inorganic fertilizers. As we discuss more fully in the next chapter, we consider that the threat posed by the possible development of resistance to some categories of pesticides may well have been underestimated by MAFF in reaching its conclusion that this is unlikely to become a major constraint on agricultural production by the end of the century.

2.37. We consider that analysis of the kind undertaken by MAFF on our behalf is desirable, not only on pollution grounds. The study could usefully be further developed, especially in seeking to place the assessments on a more quantitative basis. Other factors should be included. For example, agriculture may become increasingly important in supplying plant material for use as chemical feedstock. We think that systematic studies of this kind should find a place in the work of any department of Government.

CHAPTER III

PESTICIDES

Introduction

3.1. The subject of pesticides is probably the most emotive of those that come within our study. The use of toxic chemicals by the farmer as the principal weapon against pest and disease attack and against weeds would commonly be regarded as the most worrying of the developments that characterise modern agriculture. This is no doubt partly a legacy of the early and very widespread use of the persistent organochlorine pesticides in the decade or so after the Second World War and of the environmental damage that this was found to cause. The long-term effects on wildlife of the indiscriminate use of pesticides in America at that time were forecast by Rachel Carson in her book "Silent Spring", which played a major part in focusing public attention on these problems. The strength of this appeal to the public conscience was conveyed by Sir Julian Huxley's comment in his preface to the book, that his brother Aldous, after reading it, had said: "we are losing half the subject matter of English poetry". It may be that fears about the use of modern pesticides were exaggerated and certainly the grim future foretold by Rachel Carson has not come about. With increasing understanding of the harmful consequences that may arise from the use of pesticides, much has been done to reduce the risks and many would hold that these risks are now small in comparison with the benefits that pesticides confer. Nevertheless, it is clear from the evidence we have received that there is still anxiety about pesticide use. The quantities of chemicals used continue to rise. There is still concern that these chemicals are used more as a bludgeon than a rapier and that their possible effects on intricate ecosystems and on man may not be adequately foreseen. We have therefore attached much importance in our study to the investigation of pesticide usage and the controls and safeguards that apply to it.

The need for pesticides

3.2. Pesticides are extensively used in the agriculture of all developed countries and are being increasingly used in the developing countries. There is no doubt that these chemicals have played a crucial part in the dramatic increases in agricultural productivity that have been achieved over the last few decades. There has been much investigation of the gains in crop yields that may be attributed to the use of pesticides. These can readily be demonstrated under controlled experimental conditions but are more difficult to assess in relation to general usage where the position is complicated by other factors, including the introduction of new, higher yielding varieties of plants and the heavier use of fertilizers. The BAA provided figures for the amounts by which the yields of some crops in the UK would theoretically be reduced if pesticides were not used. The figures are based on extrapolation of data from surveys carried out in 1975 and 1976 and, for example, indicated that the cereal crop would be reduced by 24 per cent in the first year without pesticides and 45 per cent in the third. The loss in the first year is likely to be caused by the onset of pest attack, whilst the increased loss in the third year is more likely to be caused by the build up of weed seedbanks. It has been estimated that, taking the world as a whole, 30 per cent more food, cotton and other agricultural products would even now be available if they were not destroyed by pests([18]).

3.3. It must be appreciated that the use of pesticides cannot be viewed in isolation; it is an integral factor in the new systems of husbandry that have made the present high levels of agricultural production possible. The continuous cultivation of large areas of the same crop (monoculture) allows abundant production but crops grown in this manner are susceptible to outbreaks of pests and disease which can be controlled effectively only by the use of pesticides. We have referred to the importance of selective herbicides in making possible the changes that have taken place in farming methods; the need to control weeds by machine or hand cultivation was one of the main reasons for the traditional rotation of crops, and the development of control by these chemicals has been of particular importance during a time of rising labour costs and the drift of labour from the land. There is no doubt that the continued use of pesticides is essential to maintain crop yields and therefore to keep down costs of agricultural products and the price of food to consumers. Our concern is not with the question of whether pesticides should be used; it is that they should be used wisely with a balanced assessment of risks and benefits. We note here that the same considerations apply in the field of public health. Pesticides have played and continue to play a vital role in the control of insect-borne diseases, particularly in the control of malaria. Millions of lives have been saved, but it is now clear that no one insecticide is likely to prove a panacea because of the development of resistance, a problem which we discuss later (paragraphs 3.26–3.33). A broad strategy of control techniques is needed in which the use of chemicals is only one component.

Pesticide usage

3.4. Damage to crops caused by pests and disease is as old as agriculture and the history of the use of chemicals to combat these effects is a long one. Probably the earliest pesticides to be used were organic substances of natural origin such as the insecticidal mixture of natural pyrethroids extracted from a species of chrysanthemum; nicotine has been used in Europe since about 1700. Up to the Second World War, however, the chemical control of pests (including arthropods, molluscs, diseases and weeds) rested on the use of very few substances. These were mainly inorganic compounds such as copper and mercury salts and elemental sulphur as fungicides, and general poisons, for example arsenical compounds and cyanide, for insect pests. Organic compounds included various by-products, for example tar distillates, and plant extracts such as nicotine, derris and pyrethrum. Few of the pesticides available at that time acted specifically against particular pests and selectivity was usually a matter of timing of application. Their use was mainly confined to high value crops such as fruit, hops, market garden and glasshouse crops.

3.5. The modern agrochemical industry has largely developed since the war. The period of rapid increase in the availability and use of modern pesticides began with the introduction of the insecticides DDT and HCH and of the hormone-type or translocated herbicides 2,4–D, and MCPA in the late 1940s. (The term "translocated" refers to a herbicide which is absorbed by the leaves or roots of a plant and moves within the plant before killing it.) Certain insecticides also move within the plant and may, for example, pass from the roots to kill insects feeding on the leaves; these are termed systemic insecticides. In contrast, insects and plants can be poisoned directly by contact insecticides and/or herbicides. DDT (short for dichloro-diphenyl-trichloro-ethane) was so widely used that it is familiar to most people. 2,4–D (or 2,4–dichlorophenoxyacetic acid) and another translocated herbicide 2,4,5–T (see paragraphs 3.18–3.20), are best known to many through their use by US military forces in Vietnam where they were sprayed from the air in huge quantities to defoliate the forest cover.

3.6. The changes that have occurred in the numbers of chemicals available are indicated in Table 3.1 which gives chemicals in the MAFF List of Approved Products for Farmers and Growers over the period 1950 to 1975. An Approved Product is one which has satisfied the requirements of the Agricultural Chemicals Approval Scheme (ACAS) (see paragraphs 3.65–3.73).

TABLE 3.1
Chemicals in Approvals List of MAFF, 1950 to 1975

Chemical	Number listed					
	1950	1955	1960	1965	1970	1975
Natural insecticides	3	3	3	2	2	2
Contact organophosphorus insecticides	—	3	3	3	10	20
Systemic organophosphorus insecticides	—	—	3	2	16	15
Organochlorine insecticides	2	2	6	8	9	7
Organochlorine acaricides	—	—	4	4	4	3
Carbamate insecticides, acaricides	—	—	—	1	3	8
Other insecticides, acaricides	4	5	6	4	5	5
Systemic fungicides	—	—	—	—	4	11
Fungicides (powdery mildew)	—	—	—	3	4	5
Dithiocarbamate fungicides	—	1	1	7	10	10
General fungicides	—	1	3	5	8	13
Elemental fungicides	4	5	5	5	7	7
Mainly contact herbicides		2	3	8	14	19
Mainly soil herbicides		1	2	10	35	39
Mainly translocated herbicides		2	6	14	16	20
Soil fumigants	1	1	1	3	8	8
Molluscicides	1	1	1	1	2	2
Growth regulators	—	—	—	3	6	6

Source: SLY, J.M.A. in *Ecological Effects of Pesticides*, Academic Press London 1977, p2.

It is unnecessary for our purposes to explain in further detail the nature and properties of the different kinds of pesticides indicated in Table 3.1. It may be noted, however, that most insecticides and acaricides in current use fall into one of three groups of chemical compounds: organochlorines, organophosphates or carbamates. The rapid and more recent growth in number of types of herbicides will be noted. For reasons we describe later, usage of organochlorine insecticides has decreased over the last decade and growth in the availability of new chemicals has occurred in the other two groups.

3.7. The chemicals covered in Table 3.1 are active ingredients which are embodied singly, or in combinations of one or more, in products as formulations. The growth in the number of approved products is indicated in the following table which shows the number of products on the approved list in each given year.

TABLE 3.2

Growth of approved products 1944 to 1976

Year	Number of products
1944	63
1948	216
1952	352
1956	446
1960	532
1964	540
1968	783
1972	810
1976	819

Source: SLY. J.M.A. in *Ecological Effects of Pesticides,* Academic Press London 1977, p3.

3.8. We presented in Chapter II data on the growth of pesticide manufacture in the UK. Apart from the provisions of the Health and Safety (Agriculture) (Poisonous Substances) Regulations in respect of work by operators with scheduled (i.e., more toxic) substances, there is no statutory requirement to maintain records of pesticide use. The main data available, obtained on a sampling basis, are provided by the regular pesticide usage surveys conducted by the MAFF Harpenden Laboratory (formerly the Plant Pathology Laboratory) which were started in 1965. (In Scotland, the surveys carried out by DAFS started in 1974.) These surveys are conducted continuously but on a three-year cycle so that a given type of crop is generally surveyed every three years. The surveys provide one means for monitoring the extent to which pesticides are being used in accordance with the requirements of the Pesticides Safety Precautions Scheme (PSPS), and, where appropriate, incorrect uses are brought to the attention of the Advisory Committee on Pesticides (ACP), the body which operates this scheme (see paragraphs 3.59–3.64). Some data from surveys conducted over the period 1971–75 are given in Tables 3.3 and 3.4. More recent data obtained from surveys in 1977 are given in Tables 3.5–3.7.

TABLE 3.3

Recent data on extent of pesticide treatment of crops England and Wales

Crop group	*Year of survey*	*Area of crops grown (hectares)*	*Percentage of crops treated*
Cereals	1974	3,245,845	99·5
Potatoes, sugar beet and field beans	1974	434,439	98·4
Fodder, forage and seed crops	1974	1,649,484	44·8
Vegetables	1972	221,433	94
Orchards	1973	50,355	92
Hops	1975	6,414	100
Soft fruit	1975	13,123	99
Glasshouse crops	1972	3,639	97·1
Hardy nursery stock	1971	6,500	87

(*Source:* Ministry pesticide surveys)

TABLE 3.4

Types of pesticides used in agriculture and horticulture. Estimated annual average quantities of active ingredient 1971–5

England and Wales

Pesticide group	*"Spray hectares"*(a)	*Tonnes of active ingredients per year*
Insecticides		
Organochlorine compounds	148,105	132
Organophosphorus compounds	844,011	419
Other insecticides	117,232	779
Seed treatments	3,717,621	565
Fungicides	1,896,538	2,194
Herbicides	6,020,624	15,712
Other pesticides	49,438	1,960
Total	12,645,212	(b)

(*Source:* Ministry pesticide surveys)

Notes:

(a) Each application of pesticide to one hectare of land counts as one "spray hectare". Thus 10 spray hectares could mean one application to each of 10 hectares or 10 applications to one hectare.

(b) Because the active ingredients in each pesticide group are dissimilar it is meaningless to relate tonnages of one to another. We have therefore omitted the total.

3.9. A point that is not apparent from the tables is the declining use of organochlorine compounds in agriculture over a long period; however, there was evidently a substantial increase in the use of herbicides on certain crops and the more recent increase of insecticides used on cereals, especially in years with warm, dry summers. Herbicides form the majority of pesticides applied and are now used on virtually all agricultural and horticultural crops grown on any scale; it is an expanding practice to give two or more applications to a crop. It has been estimated([19]) that the total area of agricultural land in the UK treated with herbicides is in the range of 4·2 to 5·4 million hectares. Herbicides are applied to less than 10 per cent of grassland.

TABLE 3.5

Types of pesticides used on cereals, 1974 and 1977
Estimated quantities of active ingredients, England and Wales

Pesticide groups	*Spray hectares* 1974	1977	*Tonnes of active ingredients* 1974	1977
Insecticides				
Organochlorine compounds	0	1,000	0	<1
Organophosphorus compounds	41,000	294,000	17	107
Other insecticides	5,000	272,000	<1	43
Seed treatments	3,309,000	3,358,000	553	480
Fungicides	616,000	978,000	394	588
Herbicides	4,475,000	4,408,000	8,727	8,026
Other pesticides	67,000	188,000	84	263
Total	8,513,000	9,499,000		

(*Source:* Ministry pesticide surveys)

(see also footnote (b) under Table 3.4)

TABLE 3.6

Types of pesticides used on other arable crops.* 1974 and 1977
Estimated quantities of active ingredients, England and Wales

Pesticide groups	*Spray hectares* 1974	1977	*Tonnes of active ingredients* 1974	1977
Insecticides				
Organochlorine compounds	30,000	40,000	22	35
Organophosphorus compounds	469,000	274,000	191	99
Other insecticides	19,000	180,000	36	416
Seed treatments	433,000	430,000	2	2
Fungicides	599,000	616,000	696	882
Herbicides	648,000	918,000	4,835	6,131
Other pesticides	0	0	0	0
Total	2,198,000	2,458,000		

(*Source:* Ministry pesticide surveys)
*potatoes, sugar beet, field beans, rape, mustard.
(see also footnote (b) under Table 3.4)

TABLE 3.7

Frequency of pesticide treatment*

Estimated percentage of planted area of arable crops receiving particular total numbers of annual treatments

England and Wales, 1977

	Area planted (hectares)	*Number of treatments received* 0	1–3	4–6	7–more
Cereals	3,209,329	1%	55%	42%	2%
Other arable crops	476,261	1%	43%	46%	10%

(*Source:* Ministry pesticide surveys)
*Including seed treatment

3.10. It is clear that much information is collected about pesticide use in the UK, but we are not convinced that it is sufficient or that it is made available sufficiently freely. The Nature Conservancy Council (NCC) commented in its evidence that studies of the effects of pesticides on wildlife had been consistently hindered by the unwillingness of manufacturers and suppliers to give figures for the amounts of pesticides sold in this country; and that the MAFF and DAFS surveys did not necessarily give an accurate picture of the range and scale of application of many pesticides in different regions of the country. On the first point, we would say only that we can see no good reason why data on the quantities of active ingredients manufactured and sold should not be made freely available and we would urge that steps should be taken to that end. On the second point, MAFF explained that its surveys did not provide details of regional or local pesticide usage in agriculture but stated that estimates of such usage could be supplied if required. We think that it would be desirable for the principal bodies involved in collecting and using data on pesticide usage to meet, with a view to improving the arrangements. We recommend that MAFF should take the initiative in arranging such a meeting and in publishing the results.

The risks of pesticide use

3.11. Pesticides are, by design, biologically active chemicals. Mostly they act by interfering with biochemical reactions, so disrupting the normal chemical balance within the target organisms. Some pesticides are sufficiently toxic to be included in the Poisons List. These chemicals are released widely into the environment. They therefore pose possible risks to man and to wildlife and it is essential that before their use is permitted there should be very rigorous testing, designed to ensure that the risks are carefully evaluated and are acceptably small. We describe the safeguards that are applied in the development, testing and use of pesticides in a later section. Here we discuss the nature of the risks that arise.

Selectivity and persistence of pesticides

3.12. Two properties of pesticides are particularly relevant to consideration of their impact on the environment: these are selectivity and persistence. An ideal pesticide would be one that affects only the pest that it is intended to attack, is harmless to non-target organisms and breaks down into harmless constituents after achieving its purpose. This ideal, however, is far from being generally achieved.

3.13. Many modern pesticides are selective to a greater or lesser extent; that is, they are more toxic to some groups of organisms than to others. An example of a high degree of selectivity is provided by herbicides which are effective against wild oats while having little effect on wheat or barley. Some insecticides are markedly more toxic to pests than to their predators. The selectivity of a pesticide may be increased by the choice of formulation or by the method and timing of application. For example, the use of an insecticide in granular rather than liquid form or its application when crops and weeds are not in flower reduces the risk to bees. There are, however, economic and technical limits to the degree of selectivity that the agrochemical industry can achieve; indeed, the BAA indicated in its evidence that because of the very high cost of pesticide development, the tendency is now to look for chemicals which control a range of pests and diseases rather than highly specific products. This, as the Association acknowledged, is a reversal of the environmental aim of selectivity. Broad spectrum products are likely to be used for the foreseeable future, particularly against insects.

3.14. The rate of breakdown of an organic pesticide is dependent on its chemical structure and a wide variety of processes, which are affected by such factors as the soil type and acidity, temperature and moisture conditions. There is a wide range in the times of degradation, from hours to years. However, it is possible to derive a figure for the time in which a pesticide will largely have disappeared from the soil through degradation. Most of the organochlorine group of insecticides are highly persistent, that is, they exhibit a very low rate of degradation; DDT for example may persist for several years in soils. The long persistence of these chemicals was indeed seen as a major advantage, offering the prospect of long-term protection from a single application, until the environmental effects arising from this persistence began to be appreciated. The organophosphorus insecticides, in contrast, persist for only a few days or weeks. It may be noted here that with the change to less persistent materials, the active ingredients of insecticides have tended to be more acutely toxic to man and other vertebrates; thus the phasing out of persistent insecticides because of their long-term environmental effects has led to a greater risk of acute effects, though these will generally be localised. For many crop protection problems, for example the control of soil-borne pests, a reasonable degree of persistence is essential. At the other extreme, there are situations where low levels of persistence are necessary, for example to combat aphid or caterpillar attack on salad crops immediately before harvesting when the chemical must break down quickly to avoid unacceptable residues. In general, what is required is sufficiently rapid breakdown to avoid pollution but with adequate persistence for effective control. To achieve this balance is, however, a demanding requirement under the varied conditions that exist in the field.

The risks to human health

3.15. The first concern must be the effects of pesticides on human health. Pesticide exposure is one aspect of the general problem of the hazard posed by environmental chemicals. The complexities and uncertainties that arise in attempting to assess the effects of such exposure, especially possible long-term carcinogenic, teratogenic or mutagenic effects, are typical of those that exist for other chemicals, for example drugs or food additives. There is no absolute proof of safety and it must be accepted that some judgements on safety will be proved wrong by events or as scientific knowledge grows. All that can reasonably be demanded is that decisions relating to the clearance of pesticides for use or the conditions of that use reflect scientific competence and experience, and that the risks and benefits are properly considered.

3.16. There is a spectrum of exposure to pesticides. The population as a whole ingest and absorb very small amounts of pesticides as residues in food (and many receive additional exposure through the use of pesticides in homes and gardens). Workers who manufacture, formulate or apply pesticides would be expected generally to receive a greater exposure. At the other end of the spectrum are those individuals who by accident come into contact with, and assimilate, large amounts of a pesticide and suffer acute effects and sometimes death. The acute effects of pesticides are generally well understood. Unhappily, there has been no lack of incidents throughout the world to yield such knowledge, especially in developing countries. For example, pesticide application to cotton in Nicaragua is said to have led to 300 deaths and over 3,000 cases of poisoning in 1969–70([20]); in Pakistan in 1976, 2,500 workers in malaria control were poisoned by the organophosphorus insecticide malathion and five died, partly because of failure to take the necessary precautions in handling and spraying([21]). In the latter incident, the poisoning was more acute than might have been expected because of impurities in some batches of the malathion powder. In the UK, agriculture has an exceptionally good record for the safe use of pesticides. There has been only one fatality in the last ten years (in 1973) whereas, in contrast, there were nearly 100 fatal farm accidents in 1976 alone from other causes, mostly arising from the use of machinery and from falls. The proportion of reported non-fatal accidents due to pesticides is also very small: 27 in 1976, representing 0·5 per cent of the total of non-fatal accidents on farms.

3.17. Assessment of the effects of pesticides on human health must rest largely, in the first place, on the results of tests on animals and on other predictive tests that have been developed for mutagenic and carcinogenic properties. There are, however, many uncertainties involved in extrapolating animal data to man. Acute effects may be easy to assess but there are particular difficulties in assessing the risks of sustained, low-level exposure to pesticides, as to other chemicals. Epidemiological studies of workers who are occupationally exposed may provide information which would assist in the prediction of health effects that might become apparent in the general population after many years of exposure. The complexities involved in rigorous assessment are daunting. There is the possibility, for example, that pesticides may interact with one another or with other substances in the environment. It is insufficient to consider only the effects of a chemical as applied; some of the metabolic products it gives rise to may be more damaging than the original compound and more stable, thus causing greater residue problems. The whole breakdown pathway of each pesticide must be considered. We may note here by way of example a report([22]) on the herbicide atrazine which has been widely used on maize in the US. Although the herbicide itself had appeared innocuous in tests for mutagenic effects, it was apparently transformed by the plant into a substance that could cause genetic aberrations. There is also the difficulty of interpreting test results; increasingly sensitive tests disclose more subtle effects whose significance must be assessed.

3.18. Another example of the possible harmful effects of pesticides is provided by the herbicide 2,4,5–T which we mentioned in paragraph 3.5. This is a herbicide which is most effective against woody weeds. In the UK, its main use is in forestry where it is used to suppress heather, deciduous scrub and undergrowth so that newly planted conifers have room to become established. There is some concern about its use, stemming largely from its military use in Vietnam. Disquiet over indications that those exposed to the spray were suffering ill-effects was reinforced by the discovery that the product used contained relatively large quantities of an extremely poisonous impurity, 2,3,7,8-tetrachlorodibenzo-p-dioxin, (abbreviated to TCDD or dioxin). This substance is known to cause birth defects and cancer in some animals; it was dioxin which was released in the Seveso accident. Careful control of the manufacturing process can ensure that the amount of dioxin impurity is at the limit of detection and all batches of 2,4,5-T manufactured in or imported into the UK must have a certified analysis of dioxin content showing that limits laid down by the ACP are not exceeded; analyses are checked from time to time by the Laboratory of the Government Chemist. However, doubts have been raised whether any lower threshold exists in the toxicity of TCDD and, hence, whether the herbicide should continue to be used. The matter has frequently been reassessed by the ACP in the light of new knowledge; the Committee recently reaffirmed its earlier advice that 2,4,5-T can safely be used in the recommended way and has published the grounds for this advice([23]).

3.19. On the other hand, the US Environmental Protection Agency (EPA) has taken emergency action to ban certain uses of 2,4,5-T after receiving new evidence that linked its use to an unusually large incidence of miscarriages in a rural area of Oregon in which forests are exposed annually to aerial spraying of the herbicide. The ACP has yet to evaluate the information which led to the EPA's decision but it should be noted that there are major differences between the US and UK in the usage of 2,4,5-T. In the USA, about 3,000 tonnes of 2,4,5-T are used every year([24]) and that used in forestry is often applied from the air. In contrast, the ACP estimated that only about 3 tonnes were used in the UK in 1977 and this covered a variety of formulations for all purposes. Less than I tonne was used in forestry, a little more than 1 tonne in agriculture and horticulture and less than 1 tonne for all other purposes (eg in parks, on railway tracks and in gardens). Moreover, although PSPS clearance has been granted for aerial application of a number of products containing 2,4,5-T for forestry purposes only, none has been sprayed from the air for at least six years and even before then the small scale of forest planting made aerial application of 2,4,5-T a rarity in the UK.

3.20. In its recent assessment, the ACP notes that there is no evidence that 2,4,5-T has posed any risk to the health of operators applying the chemical. This is reassuring to those who might be accidentally exposed to the spray and it would seem that current practice, in accordance with the recommendations of the PSPS, gives no immediate cause for anxiety. Nevertheless, it must be recognised that public anxiety continues, and that there appear to be sufficient grounds for concern to have caused the EPA to take the unprecedented step of banning some uses of 2,4,5-T. We therefore urge that the ACP keep in close touch with the EPA on this matter, and that every encouragement be given to finding an effective and acceptable alternative to 2,4,5-T in the control of woody weeds. The example illustrates that continuing reassessment is needed of the possible hazards of some pesticides and that these may be due to impurities rather than to the pure chemical and hence vary from sample to sample.

3.21. There is particular concern about the possible long-term effects of persistent pesticides, notably organochlorine compounds such as DDT. Because of their early widespread use and their great persistence they have become widely dispersed in the environment and they constitute the most prevalent and predominant of all pesticide residues in man. They are taken up and may be concentrated in the bodies of organisms and this concentrating effect is often enhanced as one species feeds on another and the pesticide is transmitted up the food chain. Intake from food provides the primary route to man and there is clear evidence of the presence of small quantities of these compounds in human body fat. A very great amount of research has been conducted into the effects of these chemicals on man; we know of no evidence that their use has had any adverse effects. There are, however, still uncertainties. As a result of their assessment of the effects of theses compounds on man and on wildlife, the then Advisory Committee on Pesticides and other Toxic Chemicals expressed the following view: "We consider that the presence in the environment of persistent pesticides, even at low concentrations, is undesirable and we believe we should try to reduce amounts of these chemicals in the environment. We consider that the monitoring of levels of these chemicals in man, his food, wildlife and the physical environment should continue". The Committee decided that there was no case at that time (1969) for the complete withdrawal of any of the compounds under consideration. However, they made a number of detailed recommendations designed to further the reduction in the use of these chemicals which had been initiated by their earlier (1964) review.

The risks to wildlife

3.22. The effects of pesticides on non-target species are diverse and often unpredictable and here too the persistent organochlorine compounds have assumed particular importance because of their wide distribution in the environment and their accumulation in biological systems. It was found that birds of prey contained unusually large concentrations of these compounds, which were believed to be the main factor causing the decline in populations of several species over the period from about the mid 1950s to the mid 1960s. DDT and its metabolite DDE have been shown to be the main causal agent of the phenomenon of eggshell thinning which has now been demonstrated in a wide variety of bird types and species, especially predators, in various parts of the world. The NCC pointed out in its evidence that this very widespread biological effect of a pesticide went undetected for 20 years and was only detected and dated because of the availability of eggshells that had been preserved in collections. In some species the effect resulted in a high frequency of egg breakage and hence reduced breeding performance. The partial withdrawal of the persistent organochlorine compounds arising from the Advisory Committee's recommendations (para 3.21) has been considered to have removed a major threat to wild life. It has to be remembered that the greatest use for organochlorine compounds is now for non-agricultural purposes. However, we have received evidence that suggests that the decline in the level of organochlorine compounds in the environment has not been as rapid as was envisaged. Studies on the eggs of the Sparrowhawk from 14 areas of Britain from 1971 to 1977 have not demonstrated a marked decline in organochlorine residues; in some areas the amounts observed have actually increased([25]). This could be due to these compounds being more persistent in the environment than was previously thought or to their usage being more extensive than officially believed; another possibility is that the hawks had fed on migratory birds that had ingested organochlorines overseas. It may be noted, however, that in the UK these compounds are still recommended by ADAS for the control of a variety of pests (e.g. wireworms, leather jackets, Cabbage White butterfly caterpillars) and have a number of non-agricultural uses that may indeed impinge adversely on agricultural activities (see paragraph 6.69). We are unhappy that there is still a clearly discerned threat to wild life and we recommend that ACP should review the total (agricultural and industrial) use of these materials in the light of these trends. We recognise that a total ban is unlikely to be warranted: there are always likely to be very limited but specialised usages in which the benefits will outweigh the environmental costs.

3.23. The ecological impact of pesticides is a matter of major concern. In addition to other moral considerations, the preservation of the rich variety of nature is a matter of inherent importance to human happiness. Man is part of an intricate biological system and depends upon many species for survival. The interactions between species are complex and great care is required in evaluating the part played by any particular one. A change in the population of one species will affect many others linked to it through food chains. Although recently some species, such as the collared dove and certain gulls, have shown striking population increases, others (e.g. partridge, corncrake, large blue butterfly) have become rarer and we have received evidence suggesting that declining populations are more frequent([6]). It is accepted by ecologists that most of these changes are due to the disappearance of wildlife habitats (hedgerows, marshes, ponds, coppices), although pesticides have clearly contributed to the decline of some species since the Second World War. Unless the loss of wildlife habitats can be arrested, the effect of pesticides may increase in relative importance. The organophosphorus insecticides that have partly replaced the organochlorines are much less persistent but are generally much more toxic to vertebrates; thus the drift of their sprays poses new and different hazards. The newly developed synthetic pyrethroids have different properties again and if they become widely used in agriculture, they may generate another set of hazards. In addition to the introduction of new active ingredients there are changes in the methods of application (paragraph 3.91) and changes in the perceived necessity for crop treatment: in the latter connection we have already referred (paragraph 3.9) to the dramatic increase in the area in England treated with insecticides in order to control aphids on cereal crops.

The use of poison baits

3.24. We have so far considered the risks to humans and wildlife inherent in the use of pesticides for their intended purposes. Another problem, and one that demonstrates well the toxic nature of some of these substances, is the deliberate use, particularly of certain organophosphorus insecticides, in poison baits to kill not the pests for which they are intended but animals, including birds, that are regarded as vermin. A number of organisations, notably the Royal Society for the Protection of Birds (RSPB) and the NCC, drew our attention to the persistent misuse of pesticides in this way. The baits are often placed so that their effect is indiscriminate, resulting in the deaths of creatures which are not pests. The RSPB expressed concern at the effects on populations of carrion eating and rare species of birds; others noted that domestic animals, sheepdogs and badgers had been killed. Although, as yet, no human has been harmed there is a demonstrable risk. We were told of children who found hens' eggs which had been injected with an organophosphorus insecticide and left as a bait, possibly for crows. Only the green colour imparted to the eggs' contents by the pesticide warned the children that the eggs, which they were about to cook, were not wholesome.

3.25. The legal position is clear. Under the relevant Acts* it is unlawful, with limited and carefully controlled exceptions, to kill any animal, including birds, with poison. (The exceptions permit the control of rats and like vermin with poison; birds may be killed with a poison in a limited number of circumstances only by authorised persons acting in accordance with the conditions of a licence.) However, the difficulties of enforcement are obvious. It is not easy to prove that a person has laid poison unlawfully unless the act is witnessed, and this is unlikely. We strongly associate ourselves with the organisations concerned in regarding the practice as reprehensible and we support the RSPB in its campaign to demonstrate that many bird species are not the vermin that they are held to be.

The problem of resistance

3.26. Although the application of control agents—whether antibiotics or pesticides—may be initially successful in eliminating organisms that are regarded as undesirable, it is often found that the efficacy of these agents decreases with repeated application. After prolonged use, the previously sensitive organisms are found to be tolerant and are said to have developed resistance. Since this property is transmitted to the progeny of a resistant organism, it follows that a change (or mutation) in the genetic material is involved. In general, the biological agent does not cause such a mutation (although exceptions to this are known): the increase in the number of resistant

*The Protection of Animals Act 1911
The Protection of Birds Act 1954 as amended by The Potection of Birds Act 1967
The Animals (Cruel Poisons) Act 1962

organisms in a population is a manifestation of the selection of existing mutants, since only those that are resistant can survive and breed.

3.27. Most mutations of the genetic material of an organism occur at random; many will have no effect on its response to a pesticide whereas others may make it more sensitive. But, if (by an alteration in the means whereby the control agents enters the target cell, or the elaboration of means for destroying the agent before it acts at the sensitive site, or by opening up some metabolic route that by-passes the point normally inactivated by the control agent) a mutation can make the organism less sensitive to this agent, mutants inheriting this altered gene will be favoured when the population is exposed to the chemical. It is only when the agent cannot be destroyed by the affected organism, and hits a vital target that cannot be by-passed, that resistant organisms are unlikely to arise: in general, the development of resistance is inevitable if one and the same pesticide continues to be applied.

3.28. However, strategies for overcoming the disadvantages inherent in this selection of resistant organisms can be evolved. One precaution, which has proved useful with bacteria, is to use chemical control agents only when their use is necessary and not to employ them for prophylactic (or "cosmetic") purposes. This is because, in general, a resistant organism performs some vital process in a manner different from the way that is carried out in the sensitive ("wild-type") organism. Since the "wild-type", being normally the prevalent organism, is best fitted to survive in the absence of the control agent, it will tend to out-grow and replace the resistant mutant when the agent is no longer applied. For example, if a strain of bacteria sensitive to the antibiotic streptomycin grows so that the number of organisms present in a culture doubles once every hour (in the absence of antibiotic), whereas a mutant resistant to streptomycin takes just one minute longer to double in number, an initially 1:1 mixture of two strains will, after 100 hours, contain 3.1 times as many of the sensitive variety as of the resistant type. Even with this relatively slight difference in growth rate, it will take less than 9 days for the sensitive strain to outnumber the resistant type by 10:1.

3.29. Another strategy takes note of the rate at which any site on the genetic material (DNA) is likely to mutate. In general, this occurs with a frequency of between 1 in 10 million (1×10^{-7}) to 1 in 10 billion (1×10^{-10}) events. If two pesticides can be applied simultaneously which do not interfere with each other's efficacy but which act at target sites independent of each other, only organisms that had acquired simultaneously resistance to both would survive and breed. The chances of this happening is related to the product of the individual mutation rates, ie 1×10^{-7} times $1\times10^{-7}=1\times10^{-14}$ at the lowest and 1×10^{-20} at the highest, of the frequency range quoted. Both these values are, for practical purposes, negligibly small. A combination of two drugs was used to prevent the development of resistant strains of tubercle bacilli and proved to be outstandingly successful in the treatment of tuberculosis in man, and a combination of pesticides has now been recommended to avoid the development of resistant mildew on cucumber([26]).

3.30. Resistance to one compound confers automatic cross-resistance to all other compounds that are dealt with by the same mechanism in the organism. Pesticides to which resistance has developed can only be reused when the pest population has reverted to the "normal", susceptible form, but resistance usually reappears soon after the compounds are re-applied. There are no practical ways of overcoming resistance except by switching to alternative pesticides to which the pest is susceptible. In time, however, resistance develops also to these alternatives, which must again be replaced. Ultimately, this process could result in pest populations that are resistant to most if not all available compounds. It is possible that at this stage the pest will cause more damage than before chemical controls were applied; this situation could arise because natural predators have died out and because cropping techniques, changed to take advantage of the protection offered by chemical controls, provide a habitat particularly favourable to the pest. This emphasises the importance of ensuring optimum management in the use of pesticides, a point to which we shall return.

3.31. We have had some difficulty in obtaining a clear picture of the extent and seriousness of the resistance problem in the UK. We are satisfied that, for a variety of biological reasons, the problem is unlikely to become serious in the control of weeds; however, it will become of increasing importance with other pests. For example, MAFF informed us that at least ten important agricultural pests in the UK are already known to be resistant to one or more pesticides and that one or two more cases are recorded each year (the most serious recent case being resistance to organophosphorus compounds by the peach-potato aphid, an important vector of potato and sugar beet virus diseases). The Ministry acknowledged that resistance is potentially a serious problem but expressed the view that it is unlikely to become a major constraint on agricultural production by the end of the century.

3.32. In contrast to this view, scientists in many parts of the world have voiced concern at the threat to the future posed by the large and growing number of pest species that are resistant to one or more types of pesticide([27]); indeed a special study by the National Academy of Sciences of the USA identified insecticide resistance as a major problem([28]). More recently, the increasing dangers posed by pesticide resistance have been highlighted in the 1979 State of the Environment Report of the United Nations Environment Programme([29]). Even chemicals in the most recently developed group of commercial insecticides, the synthetic pyrethroids, now have some pests resistant to them. Scientists concerned with their development have written: "to ensure a long and useful life, it is essential to guard against resistance developing"([30]). We consider this a matter of serious concern.

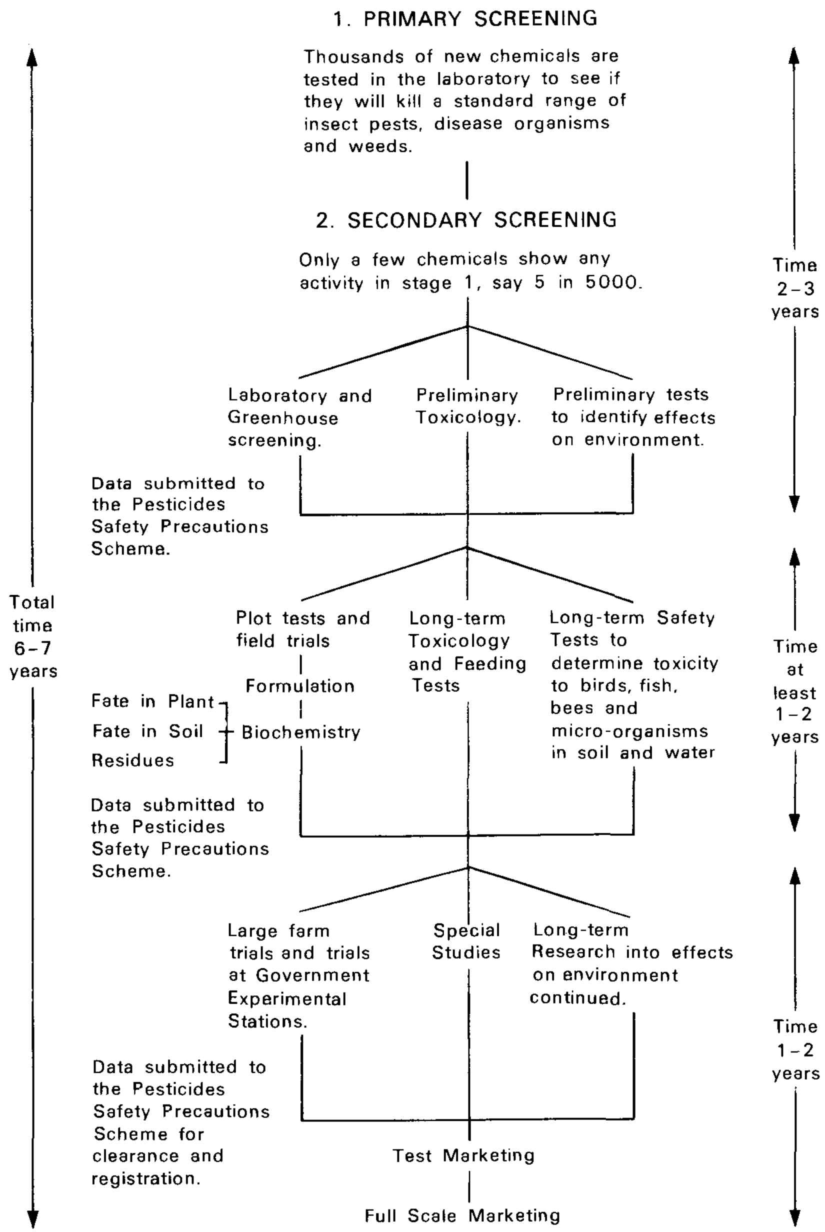
3.33. We comment later on the adequacy of research into pesticide usage. We believe attention should be given as to whether strategies could be adopted in the use of pesticides to delay the onset of resistance. One example of this might be rotation in the use of different kinds of pesticides, a situation that has recently been theoretically analysed([31]). MAFF stated that, to some degree, measures to prevent or defer the development of resistance are already taken by ADAS advisers who, backed when necessary by specialist staff, can advise farmers to minimise pesticide use and to adopt the practice of rotation in the use of different chemicals. The Ministry accepted, however, that the steps that could be taken under present arrangements are limited and that a rigorous approach to strategies against resistance would call for regional control over pesticide use. Such an approach would present many difficulties since it would call for controls over the kinds and amounts of pesticides that farmers could use. It is arguable that a farmer is entitled to use the products he considers to be necessary to protect his crops, provided they are safe, and if he were prevented from doing so he would doubtless look for compensation, whether in higher food prices or in subsidies from the taxpayer. MAFF considered that to propose such controls at present would be to over-react to the resistance problem; moreover, there is not as yet the scientific consensus on resistance problems on which the strategy could be based. The Ministry suggested that circumstances might arise in twenty years' time when controls of this kind might be needed and when they might willingly be accepted by the industry. We think this view is too sanguine and we were interested to learn that one major pesticide manufacturer had already taken steps to limit the use of a particular fungicide so as to delay the build-up of resistance. Another factor that has a bearing on the question of strategies against resistance is the expertise of operators applying pesticides. Such strategies would call for a greater degree of professionalism in pest control and perhaps for training and certification schemes for operators. It may be noted here that a study conducted by ADAS in 1976([32]) indicated that at that time less than half of these operators (in England and Wales) had received some kind of formal training and for many of these the training had been received some years previously. We comment further on this matter in paragraph 3.111.

Pesticide development

3.34. The process of discovering new, biologically active chemicals is still one of "trial and error". New chemicals are synthesised and then screened for activity by tests on representative biological organisms. We were informed that the general view of the industry is that of every 10,000 chemicals synthesised, only one is likely to reach the user as a pesticide. The stages involved in this process, which takes between five and eight years, are indicated diagramatically in Figure 3.1.

3.35. The development of a new pesticide is very costly and large sums are at risk when it is decided to construct a plant for full scale production. A paper provided by Fisons Ltd states that £10m to £15m (at 1976 values) may be spent before a marketable compound is introduced; this excludes the cost of constructing a production plant. It has beeen estimated that 40-60 per cent of the development costs of a pesticide relates to safety and environmental studies([33]).

Figure 3.1
The Development of a Pesticide

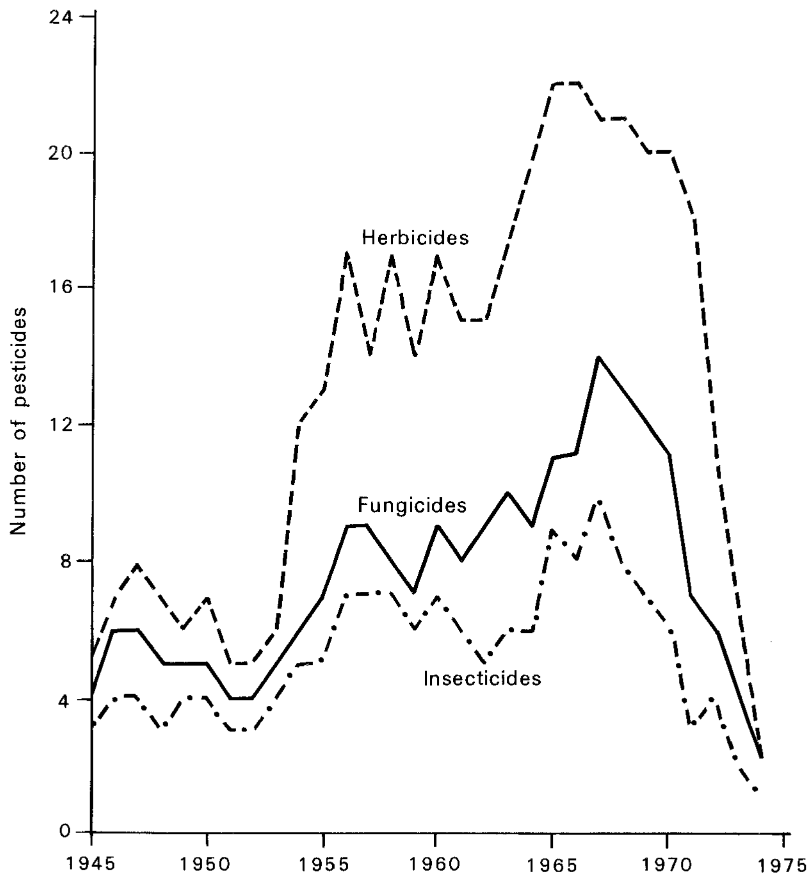


SOURCE: British Agrochemicals Association (1977)

The rate of introduction of new pesticides is slowing down; in 1956 the synthesis of 1800 chemicals led to one commercial pesticide, in 1967 the ratio was about 5000:1 and it is currently in excess of 10,000:1([34]).

Figure 3.2

Annual Introductions of Pesticides 1945–75 – 3 year moving average



The data in Figure 3.2 are based on information provided in the Pesticide Manual (BCPC 1974) on the date of introduction for the majority of the compounds described. This date can be misleading in some cases but using a three year moving average, a number of possible discrepancies can be significantly reduced

SOURCE: C.J. Lewis Proc. 18th Symp. Brit. Ecological Society (1976) p.237

3.36. In commenting on longer term developments, the BAA foresaw that this trend would continue. Because of the costs and risks involved, fewer companies will be prepared to invest in innovative research and fewer new materials will come forward. We have mentioned already the BAA view that, because of these factors, the tendency will be to look for chemicals that will control a range of pests and diseases rather than be highly specific; and that this runs counter to the environmental requirement for selectivity. We regard this as a potentially serious matter from the environmental viewpoint.

3.37. The extensive nature of the tests that are conducted on the safety and environmental effects of new pesticides is reflected in Figure 3.1. Most are made to ensure compliance with the requirements of the Pesticides Safety Precautions Scheme (PSPS). There are stages in testing, corresponding to stages in the clearance process which we describe in paragraph 3.62.

Formulations and application of pesticides

3.38. World development and manufacture of the active ingredient of pesticides is carried out mainly by a few large trans-national companies. Pesticides are normally marketed as formulated products, ready for use directly or after dilution with water. Formulation, that is the incorporation of the active ingredients into solutions, emulsions or powders, is carried out more widely. The majority of formulations are designed for use as sprays; about 500 out of the 800 or so currently approved products (see Table 3.2) are liquid formulations. Other types include baits, dusts and granules; formulations of the latter kind have increased over the last few years, mainly for herbicides and insecticides applied to the soil. Formulation chemistry is a vital part of pesticide development since the way in which a pesticide is formulated has a considerable influence on its effectiveness and its safety in use. For this reason, it is the particular formulation and not the active ingredient that must be cleared for safe use under the PSPS, and for efficacy and safety to the crop under the ACAS (see paragraph 3.65).

3.39. The aim in application is clearly to use a pesticide as economically as possible to achieve the desired result, with minimum harm to the neighbouring environment. We commented in paragraph 2.7 on the low efficiency of pesticide application. The BAA observed that the misapplication of pesticides can nullify the safety work that has gone into their development. For example, if crops are sprayed from the air in high winds the spray will drift and may adversely affect people or livestock, and may destroy plants or hedgerows or small animals nearby. Even ground spraying can be so badly done as to cause damage. The prescribed method of application of a pesticide must be cleared for safety under PSPS, since different methods can present different hazards. This is particularly so where ultra low volume* techniques or aerial spraying are involved. Clearance for methods of application is similarly required under the approval scheme (ACAS). Thus, for most pesticides, clearances are sought

*Ultra low volume (ULV) refers to a technique designed to reduce the amount of liquid that needs to be applied to crops, and hence to simplify spraying operations, by the use of very fine sprays.

by their manufacturers for those application methods current when they are marketed. However, the process of clearance for novel methods (eg ultra-low volume, controlled droplet application or ULV/CDA) appears somewhat unsatisfactory and we discuss this point in paragraphs 3.91-3.97.

Aerial spraying of pesticides

3.40. Anxiety about the aerial spraying of pesticides is apparent from much of the evidence we received and it is scarcely surprising that this is so: the use of low-flying aircraft to dispense potentially hazardous chemicals is bound to create problems of the kind described above. Moreover, the noise of the aircraft may cause annoyance or alarm to people or disturb livestock. The relatively small size of fields in the U.K., the patchwork nature of the countryside and the changeable weather all add to the risks of such untoward effects.

The extent of aerial spraying in the UK

3.41. There has been an appreciable increase in aerial spraying (see plate 3.1) over the last few years, as is shown in Table 3.8. The figures cover aerial operations involving pesticides, fertilizers and seed but do not include the spraying of woodland. Reliable figures for pesticide application alone are not available although this is thought to acount for much of the increase that has occurred. The extent of pesticide spraying will of course depend on the incidence of pest attack; for example, the area sprayed in 1976 is higher than might have been expected and this probably reflects the epidemic of aphids infesting cereals in that year. As a very rough estimate, we were told that about 200,000 hectares were sprayed with fertilizer each year (involving about 100,000 aircraft flights) and that twice this area was sprayed with pesticides (involving roughly 34,000 flights—the number being smaller because, with pesticides, an aircraft load covers a considerably larger area). In 1978, there were only 34 operators (ie aerial spraying contractors) in the country as a whole.

TABLE 3.8
Aerial Operations Survey—UK
Areas sprayed in thousands of hectares

	1972	*1973*	*1974*	*1975*	*1976*	*1977*
Fixed wing aircraft	202	254	243	295	413	442
Helicopter	72	100	91	128	137	186
Total	274	354	334	423	550	628
Total number of aircraft	53	67	76	85	90	114

3.42. There are various circumstances in which the aerial application of pesticides is advantageous. The technique can be used, for example, when land is too wet for ground machines or when the height of a crop, the scale of infestation or the area of land involved are such as to make the use of normal ground machines impracticable. It is possible that developments in ground based application techniques, for example, "tramlining",* will reduce the need for aerial application, although MAFF considered that any marked reduction was unlikely in the near future. The Ministry could make no firm prediction about probable future trends in aerial spraying but thought that there was likely to be some modest further increase.

Plate 3.1 Aerial spraying of a pesticide from a helicopter.

Photograph by courtesy of Farmers Weekly.

Present control arrangements

3.43. The control of aerial applicaton is exercised by the Civil Aviation Authority (CAA) under the Air Navigation Order 1976 made under the Civil Aviation Act 1971. Some changes in the arrangements were introduced in 1978 under an amendment to the Order. An aerial spraying operator must hold an aerial application certificate issued by the CAA. To qualify for a certificate, the operator must prepare, and make available to his operating staff, an aerial application manual which includes instructions and information relating to the safe operation of the aircraft and the safe application and handling of chemicals. A copy of this manual must be lodged with the Authority. On first application by an operator for a certificate, the operator's manual is subjected to detailed examination. In

*Tramlining: when sowing a crop, rows are missed at calculated intervals to form narrow crop free strips or "tramlines" along which the wheels of farm vehicles can pass without damaging the growing crop.

addition, a CAA inspector assigned to the operator carries out a detailed inspection of the operator's organisation; this includes management structure and responsibilities, competence of ground and flying staff, training arrangements, etc. A certificate is usually issued for one year. During its currency, the CAA inspector may carry out spot checks at the operator's base or in the field. He may be accompanied by an inspector of the Health and Safety Executive (HSE) Agricultural Inspectorate which has responsibility for inspecting the control and handling of toxic material used in agriculture. Failure of an operator to comply with the conditions applying to aerial spraying can lead to revocation of the certificate or prosecution by the CAA. In 1977, the CAA initiated prosecutions in 6 cases and sent 18 warning letters to operators.

3.44. Our principal concern is with the arrangements for safeguarding the general public and the environment from inadvertant contamination during spraying operations. There are a number of relevant requirements which must be embodied in the operator's manual. Before undertaking a spraying assignment, the operator must carry out a reconnaissance to determine whether the task is acceptable. In doing so, the operator is required to take account of factors such as: the safety of persons, farm animals, property, wild life, bees and other creatures (there is a requirement to contact the NCC if a nature reserve or site of special scientific interest lies within ¾ mile of the proposed area of operation); the possibility of deleterious effects on other crops, water supplies and fisheries; and possible annoyance and noise.

3.45. The operators may use only those pesticides which have been specifically cleared under the PSPS scheme for aerial application. The special risks that might arise from this method of application (for example, the risk to bees) are carefully assessed before clearance is given. Use of the more toxic or persistent chemicals is excluded. Initial clearance of a new pesticide for aerial application is for one year only and on a limited area; subsequent use of the chemical depends on the assessment of detailed reports from the manufacturer concerned and of other relevant data. This reporting-back procedure is repeated annually for two or three years before full clearance is given for the inclusion of the chemical in the permitted list for aerial use.

3.46. The operator's manual must describe the procedures for notifying persons who might be affected by spraying operations. Advance warning is required to be given to : the office of the Chief Constable of the area of the intended operation; as far as is practicable, the occupants of buildings and owners of livestock or susceptible crops on land having a boundary within 75 feet of a boundary of the area to be treated; any hospital, school or institution within 500 feet of any potential flight paths; and the reporting point of the local bee-keepers' spray warning scheme where this exists. Advance warning should also be given to the NCC officer concerned if this was requested at the reconnaissance stage. The manual is also required to contain instructions on techniques and precautions designed to ensure that the chemical spray is confined to the target area. These instructions cover such matters as maximum permitted windspeed and information on the effect of droplet size, aircraft height and windspeed on spray drift.

The adequacy of present control arrangements

3.47. Thus extensive controls are already applied to aerial spraying. This official machinery is augmented by action taken within the farming industry; the NFU and the National Association of Agricultural Contractors (NAAC) have produced a code of practice for aerial operators. The number of incidents leading to complaints about spraying does not appear large in relation to the scale of activity. We were informed by the NAAC that in 1976, for example, there were 116 complaints, or roughly one for each aircraft on the register. Many complaints relate to the nuisance caused by low flying aircraft rather than to the effects of spraying. MAFF submitted that there is almost no evidence that people have suffered harm from accidental contact with sprays. The facts of an incident may often be difficult to establish although we were told that investigation showed most complaints to be unfounded. One incident, in which a number of schoolchildren were taken to hospital after a nearby field was sprayed, led to prosecution of the pilot for low-flying over the school. This was the only action that could be taken since the weight of the evidence was that the children were not subjected to direct spray from the aircraft.

3.48. However, we think that incidents in which people are subjected, or believe that they are subjected, to pesticide spray, cannot be discounted even if it is subsequently shown that their fears were groundless. To be exposed unexpectedly to a spray of some unknown substance is bound to cause anxiety. We have found it particularly worrying that people who believed that they had been sprayed have found it difficult to identify the substance involved, to ascertain whether or not it was harmful and to discover what remedial action they should take.

3.49. Various incidents have been mentioned to us which suggest that the rules set by the CAA are not being sufficiently followed. In some cases, even the mandatory advance warning to the police, or to bee-keepers (where spray warning schemes exist), was apparently not given. Householders living close to the area of spraying, or farmers whose livestock might be affected, sometimes received no advance notice. As indicated in paragraph 3.46, operators are required to give such notice only "as far as is practicable"; in semi-urban areas, a need to inform everyone who might be affected would undoubtedly raise considerable difficulties. In some cases that were mentioned to us, however, we think that the people concerned should have been given advance warning under any reasonable interpretation of "as far as is practicable". We recommend that, in spite of the difficulties, advance warning of spray operations to the occupiers of adjacent land should be mandatory, and that in areas where this would be impracticable because of the numbers of people involved, the technique of aerial spraying should not be used at all.

3.50. Anxiety about aerial spraying is not confined to the general public. The ACP (see paragraph 3.61) expressed the view that more attention should be paid to the possibility of chronic effects on pilots caused by the chemicals used and the manner in which they are applied.There is particular concern about the number of crashes of crop spraying aircraft in recent years and particularly whether the functional skill of pilots may be impaired by exposure to the chemicals they carry. These matters are being considered jointly by the ACP and the CAA. There is also concern about the new practice of using drift from the windward side of a field in spraying operations; the practice saves fuel but is essentially uncontrollable.

3.51. Another aspect is the number of organisations that may be involved in aerial spraying incidents. These include the police, the CAA, the HSE (through its agricultural inspectorate), MAFF and the local authority. We were informed by MAFF that complaints about incidents are normally made to the local police or HSE office (although we would suppose that they are at least as likely to be directed to Environmental Health Offices of the local authority and we comment on this point below). The police may carry out an investigation without reference to CAA or MAFF although normally the CAA is informed. An HSE inspector normally investigates an incident and a copy of his report is sent to the CAA. The Executive is concerned with the health and safety of the operator's staff who are applying the chemicals and of the general public who may be inadvertently affected by the spraying operation. Where medical risks might be involved, the HSE calls in its Employment Medical Advisory Service. The HSE can take proceedings against operators or their personnel in appropriate cases. The CAA is primarily concerned with whether there have been breaches of aviation legislation; where the question of possible action on these grounds arises, the authority makes its own investigation.

3.52. We referred above to the routine inspections undertaken by CAA officers, sometimes accompanied by officials of the HSE. We were surprised to learn that there are only three CAA inspectors who cover the whole of the UK. The CAA stated that, in practice, this number of inspectors provides adequate control bearing in mind the number of operators and the fact that their operations tend to be concentrated in particular areas suffering infestation. The CAA inspectors visit the operators' temporary landing sites and the areas of the operation. In 1977, for example, 60 inspections were carried out, 30 being purely field inspections; these inspections covered 27 operating firms. Recently, inspection visits have taken place unannounced.

3.53. Bearing in mind the special risks associated with aerial spraying we are not satisfied that this degree of inspection is sufficient. However responsible the operators are, the nature of the industry is such that much depends on the care taken by individual pilots; several of those to whom we talked on this matter referred to a few irresponsible pilots who tend to bring the industry into disrepute. We think it essential that inspections should assess not only agricultural, but also environmental, aspects. We are concerned, for example, that the chemical being used, although cleared by the PSPS, may be inappropriate to the nature and intensity of the pest. We are also concerned that although the risks to human health and safety are the concern of the HSE, the spraying operation may be carried out in a manner that poses hazards to the environment. We see this as a MAFF responsibility. We accordingly recommend that the CAA, HSE and the Agricultural Departments jointly review the adequacy of present inspection arrangements. One particular point that should be examined is the possibility of appropriate experts from ADAS being associated with the CAA inspectorate in assessing the competence of operators on those aspects of their work that relate to its wider environmental effects.

3.54. The somewhat complicated control machinery we have described inevitably presents some difficulties to members of the public who wish to complain, or to obtain advice, about a spraying incident. We have seen accounts of the dealings of members of the public, or even local authorities, with the official bodies involved which suggest a lack of clarity in responsibilities for dealing with incidents. An incident that was brought to our notice, in which farm workers and a dairy herd were affected by spray drift, illustrates some of these problems. As this incident was described to us by the people affected, it was only by chance that they were able to find out the chemical involved, by questioning ground staff of the operator who had been present during the spraying. They had considerable difficulty in finding an authority who could advise on the risk posed by the chemical and on appropriate treatment. It appeared that the onus rested on the farmer concerned to seek veterinary assistance, to ascertain whether milk from the affected cows should be sold and to seek advice from the manufacturer of the chemical on the remedial steps to be taken. Apparently neither the farmer nor the police were given advance notice of the spraying.

3.55. We consider that there is a need to review the arrangements for dealing with incidents, with the aim of clarifying responsibilities and lines of communication so that advice is readily available to people who believe that they have been subjected to a chemical spray. We recommend that such a review should be undertaken by the organisations involved. Both the CAA and MAFF expressed reluctance to extend the number of parties to whom operators must give advance notification of spraying. We consider, however, that some extension is needed. We recommend that the Environmental Health Officer of the local authority concerned and the appropriate regional ADAS office should be given advance notification of aerial spraying and that this should state how, at any time, information on the chemical used can be obtained. In joint evidence to us, the CAA and MAFF said that they were considering the possibility of making mandatory the presence of a person on the ground, acting as a "groundmarker" during an aerial application (see Plate 3.2). We recommend that this should be done and that the groundmarker should know what substance is being applied and should be required to give the name of the operator and of the substance to anyone who inquires. We make a further recommendation concerning holders of the aerial application certificate in paragraph 3.111. where we discuss the licensing of pesticide operators.

Plate 3.2 A groundmarker guiding a crop-spraying aircraft.
Photograph supplied by Civil Aviation Authority.

Large scale aerial spraying of forests

3.56. Aerial spraying of pesticides on forests is rarely practised in this country but during 1978 the Forestry Commission carried out a large scale operation on forests of lodgepole pine in the North of Scotland. Over a period of nine days, more than 5,000 hectares were sprayed with the organophosphorus insecticide fenitrothion to prevent the widespread destruction of trees by caterpillars of the pine beauty moth, which feed on pine needles. Under the terms of a limited clearance granted by the PSPS, 1500 hectares were sprayed with ULV equipment (see footnote to paragraph 3.39) not previously used for this purpose in the UK. One of the conditions of the limited clearance was that the Forestry Commission should arrange and coordinate adequate monitoring of the environmental effects of both the ULV and conventional techniques. The operation as a whole was of some concern to a number of organisations. We therefore thought it appropriate to consider the arrangements that were made, to assess the effects of the operation and to see whether there were lessons to be learned for the future.

3.57. The Forestry Commission told us that, recognising the unusual scale of the operation and mindful of the fact that further operations of similar scale were likely, consultations with government departments and other organisations had begun before the conditional PSPS clearance for the ULV part of the operation had been given. However, the size of the threat posed by the moth was not appreciated until a few months before the optimum time for spraying. A report on the monitoring of the operation prepared by the Forestry Commission([35]) acknowledges that the haste imposed by this deadline made it difficult for the organisations concerned to reallocate staff and resources and to design and prove the experimental techniques required. When spraying began there was little known of the normal populations of wildlife in the lodgepole pine forests with which observations could be compared, neither were unsprayed control areas established. The overall assessment of the effects on wildlife was that, within the limits of the observations made, these were small or unimportant. Nevertheless the Forestry Commission expects to make more detailed observations in future operations, to determine whether there are more subtle sub-acute or chronic effects which have not yet been detected. Such effects are not unlikely. For example, insectivorous birds which find themselves well inside a large area treated with insecticide might not be able to forage far enough to reach an untreated area and might starve. Such fears were voiced recently by the RSPB([36]) in an assessment of the monitoring which was carried out during the 1978 operation.

3.58. We commend the willingness of the Forestry Commission to undertake the task of consultation and coordination and we accept that new monitoring exercises will take into account the experience now gained. However, we noted with interest the role played by the PSPS in assessing proposals for the operation and imposing conditions. We feel that there might be a case for giving such an independent assessment to all large scale spraying operations, irrespective of whether a new technique or pesticide is involved. The PSPS seems to be a most suitable forum for this in that the ACP contains a high level of scientific expertise covering most of the particular interests of the organisations who are concerned about the environmental effects of pesticides. Obviously much thought would be necessary to determine the classes of operation that should be submitted for such assessment but we would welcome consideration of this proposition as part of the wider role for the ACP and the control scheme which we advocate in paragraph 3.109.

The control scheme: The Pesticides Safety Precautions Scheme (PSPS)

3.59. The PSPS is based on a non-statutory but formal agreement between government departments and the relevant industrial associations, and has been in existence since 1957 as a scheme covering agricultural and related applications of pesticides (eg in forestry, horticulture, gardens and homes and food storage) in Great Britain. The scheme was extended to cover Northern Ireland in 1970. Starting in 1975, the scheme is being extended to cover all non-agricultural uses of pesticides.

3.60. The aim of the PSPS is to safeguard people (whether those who apply pesticides, those nearby at the time of application or consumers of treated produce), domestic and farm animals, wildlife (including beneficial insects) and the environment generally. The essence of the scheme is that manufacturers, distributors and importers who propose to intrôduce new pesticides or new uses for pesticides, undertake to seek prior official agreement and to submit test data relevant to the safety of their proposals to independent, expert scrutiny.

Figure 3.3. Involvement of Government Departments in the PSPS

DEPARTMENT (including Scottish and N Ireland counterparts)	Principal Inputs	Principal Outputs
Agriculture, Fisheries and Food (a)	Risk assessments (wildlife, fish etc) Pesticide and food Science Agronomy, entomology etc (including benefit assessments) Secretarial servicing of Advisory Committee Technical servicing (agricultural uses) of Advisory Committee	Agricultural publications and advice Food and Drugs Authority aspects (jointly with DHSS)(b)
Education and Science (a)	Appointment of (and ultimate responsibility for) Advisory Committee	—
Employment (HSE)	Risk assessments; Technical servicing of Advisory Committee } non-agricultural uses	User and public protection (b) Safety publications and advice
Environment (including NCC) (a)	Risk assessment (environmental and water)	Pollution control (including waste disposal) (b) Conservation publications and advice Protection of Birds (b)
Health and Social Security	Risk assessments (human health, including food safety)	Food and Drugs Authority aspects (jointly with MAFF) (b)
Home Office	—	Application of Poisons Rules (b)
Laboratory of the Government Chemist (Dept of Industry)	Analytical and chemical consultancy	—
Trade (CAA)	Risk assessments (aerial spraying operations)	Aerial spraying safeguards (b)

Notes (a) These Departments are also concerned with funding of related ARC and/or NERC research.
(b) Including regulatory functions.

3.61. The scheme is operated by government departments with the assistance of the ACP supported by its Scientific Sub-Committee (SSC). As Figure 3.3 shows, eight government departments (and their Scottish, Welsh and Northern Irish counterparts) are involved in the workings of the scheme, for which the ACP provides a focus. The ACP constitutes the principal source of advice to Government on pesticide matters. Its chairman and members are appointed by the Secretary of State for Education and

Science while administrative services are provided by MAFF (and technical services by MAFF and the Health and Safety Executive (HSE) respectively for agricultural and non-agricultural uses). The Committee includes representatives of Departments, experts from within Government and independent scientists with expertise in the scientific disciplines concerned (eg biology, medical science, toxicology and pharmacology). As a matter of policy there are no members having a commercial interest in the agricultural, agrochemical or allied industries. The SSC consists of scientific and medical experts who are appointed solely for their specialised knowledge and not as representatives of particular bodies. It has a number of specialised panels, including one on wildlife. Some of these, eg a panel on labelling, include representatives from industry. The SSC is concerned solely with the scientific assessment of proposals for a new pesticide, or the new use of a pesticide, in advising its parent Committee. The ACP can take other factors into account in deciding its advice to Ministers who, formally, are responsible for granting or withholding clearances. We accept that the Committee must at times make what are effectively value judgements, balancing the risk against the benefits.

3.62. We have noted that there are stages in the clearance process. There is provision for trials clearance and for limited clearance for farm scale trials which may involve use of a pesticide on an area of up to several thousand hectares, depending on the nature of the chemical and other factors. The next stage is provisional commercial clearance for a limited period of time (usually one but sometimes two years). During this period, long-term animal testing for carcinogenicity is normally completed and the manufacturer may be asked for further scientific information on the product. The final stage is clearance for unrestricted commercial sale. It is an important, indeeed vital, feature of the control scheme that at any stage the clearances given, and the precautions specified, for use of a pesticide are reviewed in the light of experience or of any fresh evidence, or because of public concern; we referred to an example of this in paragraphs 3.18–3.20. When provisional or full commercial clearance is given, safety recommendations are agreed which must appear in an agreed form on the label of the marketed product. Some clearances, where no new risks are involved, may be dealt with by the technical secretariat or the SSC without reference to the ACP but all questions of importance are referred to the main Committee.

3.63. The PSPS is non-statutory and the willing participation of the trade associations involved has undoubtedly contributed to its success. Good relations exist between the authorities and the industry which enable consultation to take place, to mutual advantage, throughout the development of a new product.

3.64. Until recently it was possible to manufacture or import and place on the market a compound which had not been cleared for safety under the PSPS and to do so without any impediment in law. However, during the course of our enquiry the Consumer Safety Act 1978 reached the Statute

Book and it included a Government amendment specifically designed to deal with this loophole. The effect is that, as explained in the Parliamentary Debates, the Minister of Agriculture can now make Regulations on "the control of pesticides"; and in practice any pesticide that was deemed unsafe could thus be kept off the market. Our impression is that this earlier "loophole" was in any case more of theory than of substance. Over 95 per cent of pesticide sales in the UK are through firms belonging to the BAA; and that Association had already taken action in the matter, with the distributors, by introducing the British Agrochemical Supply Industry Scheme (BASIS). Under this scheme, which we welcome, all registered distributors have undertaken, as a condition of their continued registration, not to sell crop protection products unless these have been cleared through the PSPS; and the BAA has since amended its constitution to oblige members to supply such pesticides only to registered distributors. A further and no less welcome feature of BASIS is that, within a relatively short period of time, all registered distributors will need to ensure that staff concerned with the distribution of crop protection products have the necessary specialised knowledge of these products, particularly on matters of safety and efficacy; and extensive training courses have been instituted for this purpose.

The Agricultural Chemicals Approval Scheme (ACAS)

3.65. The purpose of this second and separate scheme is to help users to select products of known performance which are appropriate to deal with particular pest control problems. The ACAS (which covers products for crop protection and for insect control in farm stored grain) is voluntary; it was established in 1960, replacing an earlier scheme which started in 1942. Products cannot be considered for approval under ACAS unless they have first been cleared through the PSPS. Since an annual list of approved products is published by ACAS (in the booklet "Approved Products for Farmers and Growers"), and since this constitutes the main source of official advice on the choice of pesticides, there is a considerable incentive for manufacturers to have their products included, and hence to seek PSPS clearance. Most new products cleared under the PSPS are submitted to ACAS. The ACAS publication contains not only a list of approved proprietary products; it also reproduces the recommendations for safe use derived through the PSPS and the BASIS list of registered distributors. Charges are made to manufacturers for product approval.

3.66. The scheme is basically operated by a group of scientists at the MAFF Harpenden Laboratory in consultation when necessary with specialists in other laboratories. An applicant seeking approval for a product must provide full details of the formulation and other relevant information, including details of trials carried out on the efficacy of the product. Approval is for one year only and manufacturers must apply annually for re-approval, which can be denied on the basis of new information about performance or given subject to new restrictions on use.

3.67. ACAS is backed by an Advisory Committee which is concerned with the general principles and policy relating to the scheme. The Committee is not involved with individual applications except where these raise a point of principle. Appointments to the Committee are made by MAFF and all members are from ADAS or research establishments maintained or grant-aided by the Government. The aim is to achieve an appropriate balance of scientific disciplines.

3.68. The scheme, as we have noted, is concerned solely with efficacy. Thus, for example, if it were noted from field observation that a product was having unexpected effects on bees or was reducing the earthworm population, this would be a matter for PSPS and not for ACAS. There are some areas where the interests of the two schemes may overlap. If a formulation is found to taint horticultural produce, for example, the matter has generally been regarded as one for ACAS although it might be treated as a residue problem which would be proper to the PSPS. The question of whether the two schemes should be amalgamated is currently under consideration by MAFF, prompted, amongst other things, by EEC proposals for an Acceptance Directive setting up a voluntary system whereby a pesticide could be cleared for marketing throughout the EEC; this system would embrace both safety and efficacy. MAFF indicated that the principle of integrating PSPS and ACAS appeared to command general support, although integration would present some practical difficulties and would take time to implement. One difficulty is that an extensive increase in resources would be needed to undertake the backlog of efficacy evaluation for products now outside the ACAS. In spite of such difficulties, we recommend that the schemes should be integrated. We are concerned, in particular, that information relevant to the environmental effects of pesticides should be presented to farmers in close association with that on efficacy, so that both aspects may be considered in the selection of the most appropriate pesticide for particular applications. The aim should be to assist the farmer not only to choose an efficacious product but one that will meet his needs with least risk of environmental damage. We think this aim is more likely to be achieved if safety and efficacy are considered together, within a joint scheme.

3.69. We noted in paragraph 3.65 that the ACAS booklet "Approved Products for Farmers and Growers" is the main source of official advice to farmers on the selection of pesticides for different applications; it therefore offers an important means of meeting the aim described above. The publication already provides a great deal of information but the format is such that it is not easy for a farmer to compare the properties of the various compounds that are available to deal with particular pests. We have seen examples of advisory leaflets available in the USA and they appeared to us to be more simple to follow than the UK booklet. We recommend that the form and content of the booklet be reviewed with the object of assisting the farmer to choose a chemical that will minimise the environmental impact of the application. We think, for example, that greater use might be made of coloured symbols; chemicals subject to the Poison Rules might be marked with a red circle, persistent chemicals might be marked with a yellow circle and so on. Information on the level of pest or disease attack at which spraying is likely to be needed might also be included. The amalgamation of PSPS and ACAS which we recommend would in any case make such a review appropriate.

3.70. The ACAS booklet was formerly available free on request to farmers; the costs of publication fell almost entirely on manufacturers, being recovered as an element in the charge made for the registration of new products. Increases in registration fees which were proposed in 1976 led the manufacturers to review the value of the booklet and, as a consequence, they decided that there was little point in continuing to subsidise its publication. The corresponding part of the fee was therefore abolished and MAFF introduced a charge for the booklet to cover the cost. Several factors influenced the manufacturers in reaching their decision. There was the possibility that, faced with the increase in registration fees that would otherwise occur, many companies would not submit their products for ACAS approval. On this point we note that given the amalgamation of the PSPS and ACAS, there would presumably be no possibility of opting out of the efficacy aspect of the combined scheme.

3.71. We were disturbed by another factor that influenced the manufacturers and which was put to us by the BAA. The manufacturers were apparently of the view that of the 50,000 copies of the booklet printed each year very few reached farmers, most of them tending to remain at MAFF regional offices and local wholesalers, distributors and merchants of agricultural materials. There was therefore not the benefit that might be expected from free distribution; the main beneficiaries were the advisory services and the distributors and these groups were not making an appropriate contribution to production costs.

3.72. We have no firm evidence about the distribution of the booklet but in view of the importance of the publication in enabling farmers and growers to make an informed choice between the commercial products available (the more so if it is revised on the lines recommended above), we are concerned that it should be widely recognised and used by them. We accordingly recommend that the Agricultural Departments together with the Farmers' Unions, the BAA and other organisations involved should jointly review the extent to which the booklet reaches farmers and growers and, should this appear to be necessary in the light of the review, should consider what steps should be taken to increase awareness, and encourage use, of the booklet.

3.73. The BAA advanced the view that because the booklet now had to be bought, farmers were more likely to attach value to it and to use it. We see this general argument but would not accept it in this case because of the risk of farmers relying on out-of-date copies of the booklet. We have not considered how the costs of publication should be covered. Since the booklet provides guidance on the proper use of pesticides and advertises individual products, it appears to us to be reasonable that some part at least of the cost should be borne by the manufacturers. However, it may be that other groups should make some contribution. The basis of financing publication should be considered in the review referred to above but we recommend that future editions of the booklet should be provided free to farmers, growers and contractors on request.

The policy for pesticide use

3.74. During our enquiries we have sought answers to the question: What is the underlying policy towards pesticide use? We accept that for the foreseeable future, pesticides will continue to play a vital role in food production, as also in public health. On the other hand, we have noted that the widespread use of pesticides involves some risks for people and for wildlife. It would seem desirable in principle to resolve this conflict by seeking to ensure that the amounts and toxicities of the chemicals used are as low as possible consistent with agricultural objectives, and it might be expected that such an aim would be furthered if it was embodied in declared policy for pesticide use. In presenting evidence to us, officials of the Agricultural Ministry of the Netherlands subscribed to the view that their policy could be so described and we have received written evidence that this is the official policy in at least some States in the USA and some Prefectures in Japan. There is, however, no such policy in the UK; nor does the possible need for it appear to have been considered, notwithstanding the great increases that have occurred in the usage of these chemicals. The MAFF view, and that of the agricultural and agrochemical industries, is that provided the chemicals are applied properly in accordance with the manufacturer's instructions their safety is ensured through the testing undertaken as a requirement of the PSPS; that the cost of pesticides discourages excessive use; and that the knowledge and experience of farmers, backed up by advice from manufacturers and from ADAS, ensures the necessary care in use and the selection of the most effective products.

3.75. There is much to be said for this view; there is, after all, no evidence of harm to people from pesticides when properly applied. Nevertheless, we have considerable misgivings. Our concern is that this attitude is likely to be conducive to the unnecessary application of pesticides and that it will tend to create a climate in which the investigation and exploitation of developments in control techniques which might reduce the dependence on these chemicals is not pursued with sufficient vigour. Unnecessary pesticide usage, that is usage above the minimum consistent with efficient food production, is undesirable because of the risks of pollution both direct and indirect to man and to wildlife, because it is likely to enhance the rate of the development of resistance to the pesticide and so squander its benefits and because it may destroy natural predators and so lead to subsequent and heavier infestation of a crop and to dependence on further applications that would have been unnecessary. We think there should be a considerably more questioning attitude than is now apparent, especially in the government departments concerned, to the scale of pesticide usage and we believe that this should be exemplified by a declared policy aim to reduce usage to a minimum consistent with efficient food production. We have been told by some farmers that they feel themselves to be "on a treadmill" with regard to pesticide usage, compelled by circumstances to depend on chemicals to an extent which they, as countrymen, intuitively find disturbing. We believe that positive action aimed at reducing, or at least questioning, pesticide usage would be welcomed by many.

3.76. Unnecessary pesticide usage may occur because excessive amounts are applied, whether through lack of care in following instructions for proper use or faulty equipment or application technique. The training of operators is important in this regard and we make recommendations on this point in paragraphs 3.111 and 3.112. We have mentioned (paragraph 2.7) another aspect of unnecessary usage, namely, that arising from the inherent inefficiency of present-day spraying methods. In paragraphs 3.91 to 3.97 we comment on the development of new techniques for pesticide application which offer the prospect of greater efficiency and thus of substantial reduction in the amounts that need to be used. Unnecessary usage may, however, arise from three other main causes:—

(i) the farmer's incorrect perception of his current pest problem or the efficiency or appropriateness of the pesticide used;

(ii) the farmer applies pesticides to forestall a pest or disease attack that may or may not occur. We have heard evidence that such "insurance use" of pesticides may be substantial;

(iii) pesticides are used in greater quantities and/or more frequently than would be required to produce a full yield of wholesome food, in order to ensure that the produce is of the highest quality, free of blemish, and of the best appearance: this has been termed "cosmetic control".

We discuss these causes in more detail below.

3.77. (i) *Incorrect perception.* This was examined in a recent study([37]) in which sugar beet farmers were asked to assess possible losses due to aphid attack and then to assess what amount of pesticide was required to mitigate those losses. The results obtained demonstrated that, in the great majority of cases, there was incorrect perception of the likely losses due to pest damage and that the effectiveness of pesticide application in reducing the losses was over-estimated. There is no reason to suppose the farmers in this study were atypical in being inaccurate in this way, rather the converse. Indeed, since most farmers do not leave untreated areas for comparison they have no way of checking their belief in the efficiency of their chemicals. Thus we believe that increasing emphasis must be placed on ADAS advisory activities and we welcome recent developments such as the "spray warning" leaflets and contributions to the BBC farming broadcasts: the latter are of particular importance and have considerable potential. Where appropriate, methods of supervised or of integrated control([38]) should be recommended; we welcome the recent initiative by ADAS and East Malling Research Station in developing a project on the supervised control of orchard pests([39]). We recommend that increased emphasis be placed on ADAS activities designed to improve the basis on which farmers decide their pest control strategies. The information on pesticides provided to farmers should also be improved; we referred to one aspect of this in paragraph 3.69. In this connection we welcome the ADAS "Development Farm Scheme", launched in May 1977, as an important activity that was not referred to in the official MAFF evidence offered to us.

3.78. (ii) *Insurance use.* Whether this use of pesticides can be regarded as unnecessary depends on the degree of certainty with which the risk of attack can be foreseen and on the magnitude of the risks involved. From a purely economic standpoint, a farmer may feel it prudent to spray even though the risk of infestation may not yet be apparent. Clearly, forecasting is of most value in those situations where the incidence of a pest varies greatly from season to season, particularly for those pests of which there are only occasional but very damaging outbreaks. We welcome the recent development by ADAS of the National Plant Pest and Disease Intelligence Service and we consider that there is a need for more effort to be applied to it both in operational terms and in monitoring the extent to which the advice given to farmers on spraying is followed. We deplore the practice of "calendar spraying", that is spraying at pre-set times without regard to the need for spraying, and advocate the development of a more rational basis for pesticide use in which better forecasting of the need to apply chemicals is an essential element. We were disappointed by the attitude implicit in the formal MAFF evidence: there was no reference to the National Plant Pest and Disease Intelligence Service and there appeared to be insufficient recognition that pest control tactics could and should be improved.

3.79. (iii) *Cosmetic use.* MAFF expressed the view that if this referred to the use of a pesticide solely to improve the appearance of a crop, then it was a relatively rare practice; the Ministry considered that it was generally impracticable to separate protection of appearance from protection of the crop and that the former was incidental to the latter. We accept that the two aspects of protection will generally overlap but we think that there is a real point here. The kind of consideration we have in mind may best be illustrated by an example: to ensure the complete elimination of signs of insect damage to the outside of a carrot may require a level of insecticide application well beyond what would be needed to protect the essential crop. We recognise that farmers need to meet quality standards which may be set by legislation or by traders and which will generally require that produce is free from pests and from visible traces of pest or disease damage; that the public rightly demands high quality produce; and that the provisions of the Food and Drugs Acts could lead food processors to require pesticide treatments in order to insure against the risk of prosecution. We refer in more detail to this latter aspect below. At the same time, we consider that what these requirements may mean in terms of automatic pesticide application (irrespective of any assessment of the probability of pest or disease attack and of damage that would materially affect the yield or wholesomeness of the produce) is a matter of some importance and public interest. We recommend that an investigation be undertaken of the effects that present requirements for food quality have on pesticide usage and that MAFF should take the initiative in this matter.

3.80. It was put to us by some of the larger buyers of fruit and vegetables that the market's concept of a top-grade product has not changed over the years but an increasing proportion of produce is now being classified in the higher grades. There are said to be several reasons for this, stemming ultimately from the fact that the consumer has always preferred an unblemished and attractive product. Increased purchasing power allows the consumer to be more selective and that selectivity is enhanced in supermarket shopping, where horticultural produce must sell itself or be left on the shelf. It was said that the convenience food industry depends for its existence on its ability to offer a premium product which requires very little preparation and gives little waste. Thus the standards required by the supermarkets and the processors of convenience foods have been reflected in the general standard of produce presented at wholesale markets.

3.81. The growers' response to the demands for more premium produce has been to specialise. This has been made easier by the trend towards bulk buying and contract arrangements offered by the national food processors and retail chains. It is said that this specialisation has led to improved crop management, the introduction of improved varieties and improved efficiency in pest control.

3.82. The large buyers to whom we spoke suggested that a grower, to maximise profits, will do no more than is necessary to produce the highest possible yield of a marketable product and if a product is graded he will aim for the grade carrying the highest premium. Like the Departments and the agricultural and agrochemical industries, they contended that if pest control is necessary, only essential operations will be undertaken. A top grade crop means little or no waste to producer, processor or consumer and represents an efficient use of resources.

3.83. The buyers were of the view that any tendency for a grower to use chemical pest controls unnecessarily is constrained by two factors: firstly, every pesticide application eats into profits; and secondly, the major buyers, who set the standards (which may sometimes be more selective than the statutory grades) are very sensitive to the possibility of pesticide residues. Most of their contracts specify that only approved pesticide products may be used and that harvest intervals* are adhered to strictly. Field advisers and quality controllers reinforce this. Food processors and retailers tread a narrow path between the need to supply a wholesome product, free from evidence of disease or pest attack, and the need to ensure that no significant residues of pesticide are found. A single failure to do either may invoke a prosecution under the Food and Drugs Act and in any event will damage a firm's public image.

3.84. However, we believe that this analysis is imperfect because, although

*The harvest interval is the minimum period of time that should elapse between the last application of a pesticide and the harvesting of the crop.

we recognise the balances referred to above, there is an asymmetry in the risks involved; both in regard to costs and to residues the balance will in our view normally favour the extra, unnecessary spray. The costs of an additional pesticide application are small compared with the loss in revenue that will occur if failure to apply the pesticide causes the crop to be graded in a lower quality class. The point is illustrated by the example shown in Table 3.9; it would be economic sense to apply many extra sprays if these would prevent a crop from being graded as Class II, as a result of pest damage, instead of Class I. The grade of a crop will of course depend on other factors as well as pest damage, for example, size. Nevertheless, while we accept that every pesticide application eats into profits, the example shows that quality failures may take a much bigger bite.

TABLE 3.9

The cost of pesticide application in relation to apple crop quality, based on 1971 prices

Wholesale price per tonne for Class I (A)	Wholesale price per tonne if graded as Class II (instead of Class I) (B)	Loss of income due to down-grading per tonne (A-B)	Cost per tonne of apples of an extra pesticide application
£165	£57	£108	£1.40

Source: Phoenix Fruit Farms Ltd.

3.85. The probabilities of detection for a producer who strays from the narrow path between the presence of pests or their damage and the presence of pesticide residues seems to lie largely on the former side. Any buyer, retailer, market inspector or consumer can detect insects or damage, but pesticide residues require sophisticated chemical analyses for their detection. We accept that certain major food producers monitor their own supplies, but blame for any residues detected in the sampling undertaken by the public sector at the retail point is most unlikely to be traced back to an individual farmer. We see two ways in which this balance might be made more symmetrical: by modifying the Food & Drugs Act 1955 so that the occasional presence of harmless material, inherently natural to the crop, is no longer an offence; and, secondly, by some sampling of produce for residue analysis at wholesale markets as practised in the Netherlands and in the Federal German Republic. We consider the first point below and the second in paragraphs 3.113 to 3.120.

3.86. The Food and Drugs Act 1955, section 2(1) makes it an offence to sell "to the purchaser any food or drug which is not of the nature, or not of the substance, or not of the quality, of the food or drug demanded by the purchaser". Section 3(3) of this Act provides that it shall be a defence "to prove that the presence of that matter was an unavoidable consequence of the process of collection or preparation". The decision of the Divisional Court([40]) and of the House of Lords([41]) in the case of *Smedleys Ltd. v Breed*, concerning a caterpillar in a tin of peas, has in effect removed "no negligence" as a valid defence. Lord Diplock expressed the view that those involved "can in practice ignore the subsection 3(3) altogether", it being so difficult to prove that extraneous material of this type was "unavoidably" present. In his judgement, Lord Hailsham said that although extraneous material could be unavoidably present at the time of collection, it would always be possible to remove this during preparation. The protection afforded to the vendor of unprepared food was referred to by Lord Dilhorne, who said that "if a cabbage bought on a market stall was found to contain a caterpillar it would be difficult to contend that the cabbage was not of the nature, substance or quality demanded". The Act as now interpreted thus bears more heavily on processed fruits and vegetables; modern marketing methods are leading to an increasing quantity of our produce being processed (packaged, frozen or tinned). Thus the pressures for an absolutely pest free crop are applying to an increasing area of land, with a consequent increase in pollution risks. We note that the courts accepted that the caterpillar was entirely harmless; Lord Hailsham expressed the view that the purchaser could have consumed the caterpillar, "perhaps with benefit". The producers were able to show that three and a half million tins of peas were produced that year with only four complaints of extraneous material. We recommend that in the current revision of the Food & Drugs Act the opportunity is taken to amend subsection 3(3) so that it shall be a defence if it can be shown that the material is not hazardous to health; that it might be expected to occur naturally in the food at the time of harvest; and that reasonable diligence or care has been taken to remove it. Such an amendment will, we believe, reduce somewhat the pressures for the unnecessary use of pesticides. Additionally, we note that the Law Lords questioned whether a useful purpose was served by the prosecution in the case referred to above. An amendment to the Act would serve to prevent future prosecutions in similar circumstances.

Future control arrangements

3.87. In earlier sections of this chapter we have identified our greatest single cause for concern about pesticides and we have already made various proposals for dealing with it. Before proceeding further, it may be as well to restate the former and to recapitulate on the latter.

3.88. Briefly our impression is that all concerned, both in Government and industry, have long been addressing themselves so assiduously (and, in fairness, so successfully) to the safety of individual products, and to safeguards attending on their use, that they have tended to neglect the less conspicuous yet no less significant problem of minimising overall use. The fact that our pesticides are deemed to be safe provided that recommended precautions are observed, and that the UK has such an impressive safety record in this matter, is no argument for discharging excessive quantities of these agrochemicals into our environment. Ecology and economy alike argue against this.

3.89. For these reasons we have concluded, as a starting point, that statistics on pesticide usage should be refined and made more widely available (paragraph 3.10); and that in the case of organochlorines, which were largely withdrawn on environmental grounds rather than on grounds of human safety, the ACP should review the extent of the remaining uses of these chemicals in agriculture and industry (paragraph 3.22). We have thus developed or foreshadowed a series of recommendations designed to make for a more considered and more professional approach to the volume of pesticides that are applied to the land. These include: licensing of pesticides operators (paragraph 3.33) thus complementing the welcome steps already taken to register and train those who distribute the products (paragraph 3.64); intensified advice to farmers on their strategy for plant protection (paragraph 3.77) coupled with monitoring of the take-up of such advice (paragraph 3.78); integration of the present separate schemes for evaluating the safety and efficacy of pesticides (paragraph 3.68) with free distribution of an improved booklet listing cleared and approved products (paragraphs 3.70 to 3.73); and measures to ensure that statutory obligations or marketing standards designed to improve the appearance of produce do not give rise to avoidable "insurance" or "cosmetic" applications of pesticides (paragraphs 3.79 to 3.86).

3.90. These various proposals are, in the main, detailed in character but we believe that they will, collectively, help to bring about the more questioning approach to pesticide use and the reductions in usage that we wish to see. We now consider certain more general matters that have a bearing on this aim and that relate to the control arrangements for pesticide use that we think are necessary for the future.

The development of ULV and CDA techniques

3.91. We referred briefly to these techniques in paragraphs 2.8 and 3.39. We consider the matter here since it raises issues concerning the control arrangements and since we regard the development of these techniques as highly important from the environmental viewpoint. The reason for the latter point is suggested by the terms themselves (Ultra *Low Volume* spraying and *Controlled* Droplet Application) and by the fact that, at present, these techniques are largely associated with herbicides which (as shown in Table 3.4) account for nearly 75 per cent of the active ingredient used in agriculture in the UK. It would overburden our report to describe the techniques in detail. The essentials, in very broad terms, are that pesticides are normally applied on farms in fairly diluted form by pumping them through nozzles to form a spray consisting of a mixture of large, medium and small droplets (see Plate 3.3). In this conventional method, a typical treatment would apply upwards of 250 litres of pesticide spray mixture per hectare; "low volume" applications would range upwards of 100 litres/hectare. In contrast, ULV would involve, typically, spreading about 25 litres/hectare in a more concentrated form (ie there may not necessarily be any reduction in the amount of active ingredient). The associated CDA technique enables this more concentrated form of pesticide to be projected from a spinning disc in droplets of a more uniform size which can itself be regulated (for example, by adjusting the type and speed of the disc).

3.92. It is this capacity to spread pesticides in droplets of controlled size that offers potential for reducing the usage of active ingredient. This is because, as experiments are showing, if optimum sized droplets can be established for the various formulations and crops, this may increase the proportion of pesticide applied that reaches and remains on the target plant or the immediate vicinity of its roots and thus the proportion that is effective in protecting the plant or in destroying weeds. We were informed that if ULV/CDA techniques could be perfected and generally adopted, their use might lead in time to a reduction of up to 25 per cent in the total quantity of active ingredient used for the pesticides concerned. This would be a notable environmental gain. It would also represent a gain for the farmer, not only in reducing the quantity of liquid involved; with conventional spraying either heavy equipment must be taken on to the fields or spray tanks must be frequently replenished.

Plate 3.3 Conventional spraying of pesticides.

Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

3.93. It must be ensured that these new techniques for applying pesticides are safe for operators and for members of the public who might be nearby during spraying operations; it is also important that the implications for the natural environment are assessed. The risks are greater when the spray consists of very small droplets; such a spray (with droplets in the range of 60–80 micrometres in diameter) is most effective for insecticides and acaricides. The smaller the droplets, the more readily they may be inhaled by operators or bystanders and the more readily they may drift, so presenting some of the risks that are inherent in aerial spraying; the hazards are increased by the fact that the active ingredient in the droplets is in a highly concentrated form. For these reasons, the safety of ULV/CDA techniques for insectides and fungicides has still to be established and will require major practical studies and field evaluation under UK conditions.

3.94. The PSPS covers not only new active ingredients, new formulations and extensions in the use of existing formulations but also changes in the methods of application; pesticides are cleared under the scheme for specific methods of application. Difficulties that have arisen in the clearance of chemicals for ULV/CDA application appear to suggest some deficiency in the arrangements. A rather confused situation exists where some farmers are using ULV/CDA spraying equipment with formulations that have not been cleared for this method and where the PSPS and ADAS have not been in a position to give adequate advice. There has been controversy about a particular machine which has arrived on the market; the machine releases very fine droplets from a mast above the tractor with the aim of drifting the resulting spray on to the target crop, thus posing the possible risks described above. It has been suggested to us that chemical manufacturers have been disinclined to seek the clearance of formulations for ULV/CDA application since the technique would reduce their sales of active ingredients. We think, however, that this is to ignore the highly competitive nature of the agrochemicals industry; moreover, we note that there have been over 60 clearances of herbicides for ULV/CDA, although virtually none for insecticides or fungicides.

3.95. We have formed the impression that, in the matter of ULV/CDA, the arrangements for validating new application methods have not matched the pace of innovation and the desire of farmers to make use of these techniques. The potential advantages offered by ULV/CDA from both environmental and farming viewpoints are such that we wish to see work proceed on the development and assessment of these techniques with considerably more urgency than we have discerned among the organisations involved. We recommend that studies of safety and efficacy aspects of ULV/CDA should be pressed forward and that increased resources should be devoted to this work. The unresolved problems of ULV/CDA call for research and development in the areas of both the formulation and application of pesticides; in practice, however, the former tends to be concentrated largely in industry and the latter in Government. If there are to be early advances an integrated approach is needed, by a team drawn from the several disciplines concerned, ie biologists, chemists, engineers and safety experts. The Government Departments concerned have a long history of close and effective working relationships with the industry in the operation of the PSPS: the early and approved development of ULV/CDA should be seen by both parties as a rewarding area for similar cooperation and we recommend concerted action to that end.

3.96. Generally, we see the need for a more organised approach to the assessment of new techniques for pesticide application. We have described the PSPS and ACAS and we have recommended the amalgamation of the two schemes. Under ACAS, performance data are established for individual pesticides but there is no corresponding provision for testing and reporting on the machines used to spread them; nor are we satisfied that present thinking about a combined safety and efficacy scheme takes account of this point. Other new techniques will arise; for example, in evidence to us the National Institute of Agricultural Engineering (NIAE) envisaged the use of pilotless aircraft for spraying which would fly at not more than 1 metre above the crop, and we have seen references to the spraying of pesticides from kites.

3.97. Other EEC Member Countries provide official facilities for testing various forms of farm machinery and official reports are thus available for buyer and seller alike; we are aware that the UK manufacturing and farming organisations are pressing for similar facilities so that their machinery can compete on equal terms in both home and export markets. Whatever the outcome of these representations, we see a clear need for official efficacy testing of equipment for spreading pesticides and for environmental considerations to enter fully into performance criteria. We recommend that such facilities should be established; in paragraph 5.55 we make a similar recommendation in respect of equipment for the treatment and spreading of slurry from intensive livestock units. For pesticides, these testing facilities would form an integral part of a combined PSPS and ACAS scheme and it might be useful to illustrate our intentions with regard to the scope of such a scheme by reference to a possible future development. We envisage that, just as only a limited range of pesticides are now cleared for aerial spraying, the time may come when pesticides will not be cleared for present day "conventional" spraying if other techniques, such as ULV/CDA, have proved equally safe, more efficient and preferable on environmental grounds.

The PSPS: the statutory versus voluntary question

3.98. We have explained that the PSPS is a non-statutory control scheme. The question of whether control should be placed on a statutory footing is one of long standing and one that the Commission itself has previously considered on two occasions as we describe below. The proposed integration of PSPS and ACAS (which is also, at present, a non-statutory scheme) will add to controversy on this matter.

3.99. In its First Report([42]) the Commission strongly supported a recommendation that had previously been made in a report (1967) by the ACP([43]) (then the Advisory Committee on Pesticides and Other Toxic Chemicals) that a mandatory scheme should replace the existing voluntary one, and expressed the view that this change would in the end be inevitable. The ACP had been led to make its recommendation partly because of anxiety about the "loophole" referred to in paragraph 3.64 and partly because of its concern about the need to restrict the use of the persistent organochlorine pesticides. The Advisory Committee's recommendation was also supported at the time by the (then) Association of British Manufacturers of Agricultural Chemicals. Proposed new legislation, a Pesticide Bill, was in fact being drafted. If enacted, this would have made it an offence to sell, supply or import a pesticide product which had not been licensed by the Government. It provided, amongst other things, for the making of regulations requiring records to be kept of pesticide purchase and usage and there were proposals to make the misuse of certain pesticides in baits to kill wild birds an offence. The matter was, however, reassessed by the Advisory Committee and following consultation with the Commission, and with its agreement, the then Minister of Agriculture announced in April 1972([44]) that because the PSPS was now working so effectively it had been decided that there was no need to proceed with legislation at that time. The Commission maintained, however, as a matter of principle, that statutory control should not be ruled out as the ultimate sanction.

3.100. The matter was again considered in the Commission's Fourth Report (1974)([45]) where the Commission noted that in view of the continued downward trend in the use of organochlorine compounds, the replacement of the voluntary system by a statutory one did not appear to be justified at present. This conclusion was reached solely on the basis of organochlorine usage and in the context of a general review of developments in the field of environmental pollution. The Commission was unable at that time to undertake the more searching enquiry into pesticide usage that has been possible in our present study. We have therefore felt ourselves to be uninhibited by the Commission's previous and limited enquiries in reaching our conclusions in this matter.

3.101. Although there appear to us to be several detailed points of weakness in the PSPS, and we discuss these below, we have no reason to doubt that the scheme has been effective in assessing the safety of pesticides and in specifying safeguards for their use. It has been put to us, and we generally accept, that the standards set by the scheme are high and recognised as such internationally. We are considerably less satisfied, however, that similar care is taken in the use of pesticides in practice. We are concerned about the scale of usage; about the quality of the decisions taken on the need to use pesticides and on the choice of pesticides for particular applications; and about the adverse environmental effects of excessive use or of misuse.

3.102. We note first some general points that have a bearing on the case for a statutory control scheme. It appears to us that stricter controls over pesticide use are likely to be needed in the future in order to support strategies for counteracting the development of resistance, and a statutory scheme would provide a framework within which such controls could be exercised. We think that it is, to a degree, anomalous that, at a time when there is concern about the hazards posed by toxic chemicals in the environment, and when statutory controls designed to ensure adequate testing of new chemicals have been introduced or are envisaged in most industrial countries, the control of pesticides should continue on a non-statutory basis. A further point is the possible wider use in future of other pest control agents, for example, bacteria or viruses, which may pose new hazards. We note in passing that, in the USA, the EPA has recently approved the use of suspensions of the bacterium

Agrobacterium radiobacter for applications to fruit trees to protect them from crown gall disease. While we recognise that powers are now available, under the Consumer Safety Act 1978, to ban a particular pesticide (see paragraph 3.64), we see this as only a limited "stop-gap" measure which falls far short of providing a statutory basis for control over pesticide use.

3.103. The case for a statutory control scheme depends in the first place, however, on whether this would materially reduce misuse and bad practices in the application of pesticides. We accept that making the PSPS statutory would not in itself lead to any changes either in the kind of pesticides cleared for marketing in this country or in the recommended precautions attendant on their use. But if the conditions set for safe and efficient use were made mandatory and could effectively be enforced, then legislation might be justified to give the control scheme the necessary cutting edge. Effective enforcement would clearly present great difficulties; it seems likely that it would call for additional staff and resources which would be hard to justify in terms of gains in either safety, or efficiency or both. Even accepting the difficulty of enforcement, however, it might be argued that bad practices would be more strongly discouraged if the requirements set for safe use of pesticides under the PSPS had legal force. This certainly appears to be the view of the several environmental organisations that urged in their evidence that the control scheme should be made statutory.

3.104. We have considered carefully the arguments that have been advanced in evidence against a change to a mandatory system, especially by the ACP. The Committee expressed the view that a mandatory system would be relatively inflexible, costly and time-consuming, that it would tie up additional toxicological expertise to no good effect at a time when this expertise is in short supply, that it would require a considerable increase in the number of civil servants required to operate it, but that it would not lead to improved standards of assessment. Concern that the change might have such effects was also expressed by the BAA. The Association pointed out that many companies had to clear their products through the rigid and sometimes legalistic statutory schemes in other countries and that it would thus make little difference to the industry if the UK scheme were made statutory. If that were to happen, however, the BAA strongly urged that so far as possible the PSPS with its present method of working and in more or less its present form should be given statutory backing, rather than that a detailed new Pesticide Act should be brought in. The industry feared that during the passage of new legislation, political, as opposed to scientific, considerations might produce an Act compliance with which would entail considerable increases in expense, staff and time in companies and in Government with no compensating gains in safety or efficiency.

3.105. While we would not accept that a change to a statutory scheme need have adverse effects to the degree foreseen by the ACP, we see some force in these arguments. The case for a full statutory scheme does not appear to us to be strong enough to justify the risk of seriously disturbing control arrangements which have served the country so well. At the same time, we are not content with the present situation. We believe that Ministers should have power to act quickly should circumstances change and should the non-statutory system cease to operate efficiently; and we also think that it is desirable, given the importance of this area of pollution control, that there should be statutory recognition of the Minister's power to appoint an advisory committee or advisory committees on pesticides.

3.106. Our aim, therefore, has been to secure a statutory basis for the control scheme which would allow the present arrangements to continue undisturbed so long as they operate successfully, combined with authority to take immediate action to vary or replace the system. We accordingly recommend that the appropriate Ministers should take general reserve powers which would enable them to make regulations for the control of pesticides and to appoint such advisory bodies for that purpose as they see fit. We see the latter provision as a form of statutory recognition of a body such as the ACP. We think that a possible additional advantage of this proposal is that it would bring pesticide control in the UK more into line with the systems which operate in other Member Countries of the European Community.

Confidentiality and the PSPS

3.107. The information received under the PSPS is confidential and we recognise that a proportion of this must remain so to protect the commercial interests of the pesticide manufacturers. However, we have received evidence that those concerned with studying the effects of pesticides on a variety of living organisms may be hindered in their scientific work by this confidentiality being carried to unnecessary lengths. We think that refusal to release information on grounds of confidentiality tends to become a reflex action, without specific reference to the question of whether commercial interests are truly at risk. By way of example, we mention the response received by a scientist who sought information from a manufacturer in following up a point that was put to him by one of our members about the possible risks posed by a particular chemical. The information was refused with the comment that toxicological data, quoted out of context, could easily be used to mislead the public and create unnecessary concern. The point was also made that unless all companies were required to divulge information, no one company could be expected to "step out of line". We note here that we have also received evidence that in some other countries (especially the USA) more information is made available and this may relate to the same chemicals as are used in the UK.

3.108. The confidentiality question was also mentioned to us by the NWC in relation to the clearance through the PSPS of aquatic herbicides.* A representative of the NWC takes full part in the work of the ACP Scientific Sub-

*Aquatic herbicides are used to control the growth of vegetation in water and on the banks of watercourses, largely to keep channels open for efficient land drainage. As with pesticides intended for aerial application, such products are subject to special attention during PSPS clearance; for example, extra information is required on toxicity to aquatic animals and on the persistence of residues in water.

Committee when an aquatic herbicide is under consideration. It was suggested to us, however, that the Council's representative is prevented from adequately discussing the matter with expert colleagues in the water industry by the confidentiality placed on data submitted by manufacturers to the PSPS. We recommend that the ACP (or the body subsuming its functions following consideration of our report) should, in consultation with the manufacturers, review its arrangement on confidentiality with the aim of ensuring that information is not unnecessarily withheld, particularly from those engaged in research in this field.

Other aspects of the work of the ACP

3.109. The ACP constitutes the main source of advice to the Government on pesticide matters. It might be thought that arising from this general responsibility the Committee would concern itself with the wider issues raised by pesticides; for example, with the implications of the growing total usage of these compounds. In fact, the ACP is largely concerned with the considerable workload that is imposed by the PSPS. We have concluded that in addition to the amalgamation of PSPS and ACAS, which we recommended above, the Committee's role should be extended in other ways. Firstly, we think that the ACP should be required to publish a periodic report on its work and on trends in pesticide usage. In doing this they should receive a report from the MAFF Working Party on Pesticide Residues. Such reports would be valuable in increasing public awareness of the Committee's work and in providing a synoptic view of developments and problems in the field of pesticide use. Secondly, we think that the Committee should be empowered under its terms of reference to consider and to advise on research needs in the pesticides field. It appears to us that in view of its involvement with questions of pesticide safety, the Committee is in a good position to identify areas where research is needed. No doubt such matters are already brought by informal means to the attention of the departments and agencies concerned with such research. We consider, however, that a formal arrangement is appropriate and should be introduced. Thirdly, we believe that the ACP should take a more active role in following up the ecological effects of pesticides after their release. We think that unforeseen effects could be brought to light by a system analogous to the "yellow card" method used by doctors in respect of new drugs. Local ADAS, NCC and similar officials should be provided with cards on which they could return information of observations of apparently untoward events following the release of a new pesticide. This would provide a widespread network for detecting or evaluating side effects. The NCC already has an important role in alerting the ACP, ADAS and others to unexpected side effects of pesticides. We were pleased to hear during the course of our study, that it has had an increase in scientific staff so that it may maintain its capability in this respect.

3.110. We recognise that these changes, in particular the reporting requirement, may call for additional resources for the Committee and its secretariat. We have not considered these resource implications in detail but we believe they would be small in relation to the benefits that would come from this extension of the Committee's role. The formal responsibility for appointments to the ACP, and for its terms of reference, rests with the Department of Education and Science (DES). We recommend that the Department, in consultation as necessary with the Agricultural and Environmental Departments, should consider how best to implement these changes.

The licensing of pesticide operators

3.111. We have referred in several places to the evidence we have received on the misuse of pesticides, to the need for skill and precision in the application of such biologically active substances, to the growing sophistication of pest control techniques and to the possible future need to control the use of particular compounds as a means of combating the development of pest resistance to pesticides. Although the safety record in Britain is good, safety and environmental considerations will become more pressing. We believe that the best protection against the unnecessary use of pesticides by misapplication is the development of a professional attitude towards pesticide application. We therefore recommend that persons who apply pesticides commercially, whether to land or to safeguard stored products, should be required to obtain a commercial pesticide operator's licence: the possession of such a licence by pilots who apply pesticides should be a condition of the Aerial Application Certificate. The licences should be issued by the Agricultural Departments on the production of evidence that the applicant had satisfactorily completed approved courses of training. Approval of such courses, which could be provided by the appropriate training board, industry or educational establishments, should be the responsibility either of the Agricultural Departments or of the appropriate validating body for associated tests, eg, the National Proficiency Tests Council in the case of farm workers in England and Wales. The implications for the many operators in the various non-agricultural sectors would need to be considered separately.

3.112. We note that in a comparable scheme in the State of Indiana, USA, licensees are required to obtain a total number of course units and these may be accumulated from courses of various durations and standards and hence unit value: we believe such flexibility has much to commend it. The licences would need to be renewed within a specified period. We envisage that persons applying pesticides commercially might be asked to produce their licence by an HSE inspector, an EHO, water authority inspector (or police officer). The legislation that is enacted to permit the introduction of this licensing system should stipulate that the application of pesticides commercially without a valid licence constitutes an offence: the officers listed above would be able to bring cases before the Magistrates' Court. We also consider that farmers, their direct employees and others who apply pesticides on a similar scale should be encouraged to take the approved courses on pesticides and their application: we do not envisage that, at present, they would be included in the licence scheme but completion of suitable courses might make an employee eligible for craftsman status.

Monitoring and control of pesticide residues in food

3.113. High residue levels in a crop may indicate that excessive amounts of pesticide have been applied or that prescribed harvest intervals (see footnote to paragraph 3.83) have not been observed. We noted earlier (paragraph 3.85) that in the UK farm produce containing excessive levels of pesticide residues is unlikely to be traced back to the farmer concerned. We have therefore considered the arrangements that exist in the UK for the monitoring and control of pesticide residues in food and we have also looked at the methods used in other EEC Member Countries.

3.114. General powers exist under the Food and Drugs legislation which enable local authorities to take samples of food offered for retail sale and to bring prosecutions if excessive pesticide levels are found. Apart from this sampling, the monitoring of residues is undertaken in two other ways, co-ordinated by a Working Party on Pesticide Residues which reports to the ACP and to the Steering Group on Food Surveillance.

3.115. The first of these ways is a quarterly total diet survey using food, obtained from shops throughout the UK, which is prepared and cooked as though for eating(46). The results of analyses of this foodstuff are used to derive an average value for the amount of pesticide consumed daily in the diet. The purpose of the surveys is to provide national signals about pesticide residue levels and to indicate any particular problem areas that may call for local investigations.

3.116. Secondly, we understand that there is some monitoring of individual foodstuffs which are obtained directly from farms or from other points in the distribution chain. Such surveys are designed *ad hoc*; for example, to follow up on warning signals thrown up by the total diet studies or to monitor the effect of changes in the pattern of pesticide usage which might be indicated by the pesticide usage surveys (paragraph 3.8). The purpose of this monitoring is to ascertain whether the voluntary controls on usage remain effective and to ensure that the recommendations relating to usage are correct in practice; it is not intended to identify farmers and growers who are misusing pesticides. For example, some recent high levels of fungicide on glasshouse lettuce have led to an adjustment in the prescribed harvest interval and monitoring will continue to see if this has the desired effect. In this case the high levels were caused not by a disregard of the harvest interval but by the fact that, in practice, it was too short. We note here that we found it difficult to establish how much monitoring of this kind is carried out; MAFF was unable to estimate readily the resources allocated to it because many laboratories are involved and the work is linked with other activities.

3.117. MAFF informed us that both the harvest intervals and the recommended limits for pesticide residues incorporate wide safety margins; there is negligible risk of toxic effects even if levels approach these limits and there is no evidence from the surveys of widespread disregard of harvest intervals or recommended application rates. However, it is difficult to obtain quantitative evidence on the extent to which pesticides are correctly or incorrectly applied. We have seen only one attempt to do this([47]) and we noted with concern an indication that the non-observance of harvest intervals may be more common than MAFF believe. We recommend that MAFF should take note of this and that monitoring surveys should be designed to test the matter. We also recommend that consideration should be given to the use of "spot check" surveys and to the possibility of using the results, if these indicate malpractice, to influence farmers individually and collectively.

3.118. An important general issue that arises concerns the difference in approach between the UK and other Member Countries of the European Community in the control of pesticide residues. In contrast to the arrangements in the UK described above, other Member Countries seek to control residues by routine sampling and testing of individual foodstuffs and by removing from the market any consignments found to contain residues exceeding prescribed levels. Such a system might be thought not only to protect the consumer but also to provide powerful incentives for producers to use pesticides carefully. Successive UK Administrations have resisted the EEC approach, broadly on the grounds that in practice a control system with this dual aim is not calculated to serve either of its purposes to best advantage and cannot achieve results commensurate with the cost in terms of both public expenditure and scarce scientific resources.

3.119. In principle, we find the EEC approach attractive. We think it highly desirable that where high residue levels are detected, the farmers or growers concerned can be identified and pressure brought to bear to deter them from misuse of pesticides; hence our recommendation for "spot check" surveys (paragraph 3.117). At the same time, we recognise that the arguments for and against a system of this kind raise a number of issues that we have not examined in detail. To take one example, there is the question of how far such a system is truly practicable: between the spraying of a crop and the market testing of the harvested product lies the chain of storage, processing and distribution within which residues can decline and through which it can be increasingly difficult to trace the grower of offending produce, much less to found an effective prosecution against him; and in any case, such produce, particularly if perishable, is liable to have been sold before laboratory analyses are available as a basis for removing it from the market. It has in fact been suggested to us that in those countries where this sampling and testing system is used, it is largely confined to the monitoring of imported foodstuffs.

3.120. We think that this matter is important and that the arguments relating to the design of the monitoring system, and to the practicability and desirability of building in arrangements such that there is feedback to growers, deserve to be fully set out and widely discussed. We would wish to see a detailed assessment of the UK approach set against the realities of continental practice, bringing out the interplay between the requirements for food protection and environmental protection and the cost/benefit aspects. We recommend that a study be undertaken by MAFF to provide the basis for public debate on these issues.

Research: Its role in reducing pesticide usage

3.121. We have acknowledged the need for pesticides in modern agriculture and the fact that they will continue to play an important part in the future. Also, we have stated clearly our desire to see an explicit official commitment to reduce pesticide usage to the minimum necessary to maintain yields and productivity. If such a commitment is adopted, some reordering of priorities must be expected in research and development programmes. We discuss here the existing programmes and indicate those areas where we think changes in emphasis are necessary.

3.122. A great amount of expert research lies behind the commercial development of a new pesticide. We give an indication of the scale of this work and of the proportion directed to environmental studies in paragraph 3.35. We are satisfied that pesticide manufacturers do all that is necessary to meet the requirements of the PSPS as regards the safety in use of pesticides and their immediate impact on the environment. Manufacturers are well aware of the problems posed by the resistance of pests to their products and we understand that they are becoming increasingly involved in the development of techniques to delay the onset of resistance. These include recommendations for usage which amount to strategic restrictions. We welcome such developments. These will tend to minimise the use of insecticides, fungicides etc. but we note that they will have no effect on the use of herbicides which form the largest proportion of all the pesticides applied in this country. It is to the public sector that we now turn to see what is being done to minimise the use of all types of pesticide.

3.123. Most of the state-sponsored research on pest control and pesticides is undertaken by the ARC, and by MAFF through commissions with its own ADAS and with the ARC. The basic objective of this work is to increase the efficiency and productivity of UK agriculture. Largely, it falls under the general heading of crop protection, where the remit is to prevent losses due to pests, diseases and weeds and to improve methods of crop protection. In 1976/77 expenditure by MAFF and ARC on all aspects of agricultural research and development amounted to about £50m. Of this sum, a little under £6m was devoted explicitly to crop protection. It was clear from the information we received that by far the larger part of this £6m was related to the use of pesticides: for example, research on herbicides and their use in systems for weed control is the major topic at the ARC Weed Research Organisation with an annual budget of £¾m. We saw that many of the projects, although undertaken without the specific intention of abating or preventing harm to the environment, would reduce the risk of pollution if they succeeded in their stated objective.

3.124. Many of the hazards arising from the use of pesticides are the result of inefficient techniques of application: if the probability of the pesticide reaching its target can be increased, less will be needed to achieve the desired level of control and consequential risks will be reduced. The ARC told us that all research stations with an interest in pest control have *ad hoc* programmes designed to improve the efficiency of existing methods but that there are more fundamental programmes of research on new concepts of application with the long term aim of reducing the amount of pesticide needed for effective control. Apart from some work on Controlled Droplet Application, this appears to be directed mostly to the use of pesticides in orchards. Pest control in orchard management is important but we feel that the scope of this basic work on application methods should be widened. We are sure that great improvements in the efficiency of pesticide application are possible and we recommend that greater emphasis should be placed on the development of new techniques which can be used throughout agriculture. In paragraph 3.9 we noted the continuing increase in the use of herbicides in arable farming and the marked increase in the use of insecticides on cereals. Techniques which significantly reduce the use of pesticides in arable farming could potentially reduce the amount of pesticide applied to 20 per cent of the land surface of the UK.

3.125. Even if the efficiency of application is improved, the possibility that pesticides are used unnecessarily remains: this possibility is reduced if the user is informed accurately of the need to apply pesticides and the optimum time at which to do it. To provide this information, the incidence of diseases or pests must be accurately monitored and the factors which lead to the spread of disease or the growth of a pest population must be known. It is possible to do this: we note here the success of the scheme for forecasting populations of the black bean aphid and the scheme which gives potato growers a weekly appraisal of the probability of potato blight arising. We welcome recent initiatives such as the "supervised control" scheme for orchard pests which ADAS is seeking to introduce into general commercial practice. Here the grower himself monitors pest populations in his orchards, spraying only if certain threshold conditions are reached. We find these monitoring and forecasting techniques very attractive and strongly urge that their application be extended as widely as possible. To this end we recommend an expansion of the underlying research on the factors determining the incidence of diseases and pests and on the measurement of economic threshold levels.

3.126. We have discussed the growth of pest resistance to pesticides in paragraphs 3.26–33. It is, to us, a matter of some concern, since the build up of resistance leads to gradual increases in the amount of pesticide applied before the product is acknowledged to give no useful control. Greater attention should be given now to devising strategies which can be adopted to delay the onset of resistance as long as possible. This would increase the probability that a new pesticide or an alternative control measure will be available should an existing pesticide cease to be effective. Before such strategies can be devised there is much to be learned about the genetics of pest populations and the nature of resistance. There is work in progress at present: the ARC told us of work on aphids and cereal mildews which aims to provide an understanding of how resistance develops and how it can be forestalled. The work should be strengthened and broadened. The techniques of monitoring and forecasting to which we refer in the paragraph above have an obvious relevance to any strategy for delaying the onset of resistance. This leads to the concept of integrated pest control which we discuss in paragraph 3.128.

3.127. The amount of pesticide applied can be reduced if alternative methods of control are substituted. An important approach is to breed crop varieties which are resistant to the pest or disease. Some modern cereal varieties combine high yield with resistance to fungal infection, with telling effects on pesticide usage. Most winter wheat grown in the UK now has resistance to eyespot disease but this is not the case in the Federal German Republic: crop areas and yields are similar yet the area of crop treated with fungicide in the UK is one third of that in Germany. Varieties of potato are now available which are resistant to the cyst nematode: when used in rotation with susceptible varieties, nematode populations in the soil are kept below economically damaging levels. Crops can be made unattractive to insect pests; we have been told of work to develop varieties of sugar beet which do not support an aphid population, thus reducing the risk of virus diseases spreading. Against weeds, crops bred to grow quickly in the period just after germination smother out competing weeds and reduce the need for persistent herbicides. All these are significant and encouraging steps but we feel that more can be done to exploit the natural resistance of crops to pests. The temptation to concentrate on yield and leave pest and disease control to the chemist is one which the plant breeder must avoid.

3.128. Populations of living things are naturally subject to a number of controls. The population of an insect, for example, is controlled by its breeding habits, the climate, the availability of host plants or animals, its susceptibility to disease and the extent to which it is preyed on. It is possible to manipulate these factors and we give examples of such biological control in paragraph 2.10. However, it is unlikely that wholly biological controls will become generally applicable outside closely controlled environments, such as glass houses, or outside large areas of monoculture, such as forests. This is not to say that the development of biological control techniques should be given less priority; they have a future as part of widely based pest control strategies which embrace all the techniques which we have discussed. It is in the widespread adoption of such integrated control schemes that we see the possibility of significantly reducing the use of pesticides in agriculture. A start has been made: we note as an example the scheme, now being evaluated, for the control of the damson hop aphid (a pest in hopfields). We note, also, the collaboration between the ARC and the Game Conservancy on a study of the cereal ecosystem which could lead to integrated control measures against cereal pests. Much more could be done and we recommend a strong commitment to applying the concepts of integrated control as widely as possible.

CHAPTER IV

NITROGEN FERTILIZERS

Introduction

4.1. As explained in Chapter 2, we have investigated the use of nitrogenous fertilizers, principally as they relate to the problem of rising nitrate levels in some water supplies. Our concern stems mainly from the possible health hazards that have been attributed to nitrates, either directly as a causative factor of methaemoglobinaemia in infants, or indirectly as the source of one of the components required for the synthesis of nitrosamines and nitrosamides, some of which have been shown to cause cancers in laboratory animals.

4.2. We have also examined the contribution of nitrate to the nutrient enrichment of inland waters, which results in the excessive growth of algae. Furthermore, and as far as the knowledge available permitted us to do so, we have considered possible damage to the ozone layer of the earth's atmosphere by gaseous oxides of nitrogen, released from nitrate in the soil.

Possible health hazards associated with nitrates

Methaemoglobinaemia

4.3. Oxygen is required by all human tissues, to enable them to combust the food materials brought to them by the blood and other body fluids. The oxygen is carried from the lungs by combining with haemoglobin in the red blood corpuscles to form oxyhaemoglobin: oxygen is released from this carrier in the tissues, and the desoxyhaemoglobin left behind is returned to the lungs for re-oxygenation. For the haemoglobin to be able to act as a carrier, the iron atom within the molecule has to be in the reduced (Fe II) state; if the iron atom becomes oxidised (Fe III), the pigment is converted into methaemoglobin, which cannot participate in oxygen transport. If sufficient methaemoglobin is present in the blood it produces clinical symptoms of oxygen starvation, the main characteristic being cyanosis, sometimes seen as a bluish discolouration of the lips. The condition is known as methaemoglobinaemia and, for the reasons we describe below, it is largely confined to infants in the first few months of life. Given recognition of the symptoms and appropriate treatment, recovery is rapid and complete.

4.4. Since haemoglobin is constantly exposed to oxidative stresses, small amounts of methaemoglobin are formed all the time. In the normal adult, these are efficiently reduced again in a reaction catalysed by an enzyme termed methaemoglobin reductase; however, this enzyme develops only gradually after birth. Any condition that favours the formation of methaemoglobin is thus likely to pose a threat to infants up to about 6 months old. An additional factor that exacerbates this hazard to infants is that about 80 per cent of the blood pigment of the new-born is in a form (foetal haemoglobin) peculiarly susceptible to oxidation; this form is only gradually replaced by the more oxidation-resistant adult variety.

4.5. Nitrate in itself is relatively non-toxic but, when ingested in food or water, it is partly reduced to nitrite by bacteria in the mouth and in the gut: nitrite is a powerful oxidising agent which is able to convert haemoglobin in the blood to methaemoglobin. The reduction of nitrate to nitrite may also occur to a relatively greater extent in infants than in healthy adults as infants tend to have less acid in their gastric juice; this allows nitrate-reducing bacteria to grow in the upper gastro-intestinal tract from which nitrite is absorbed. The effect is enhanced if the infant has an infection causing diarrhoea. Other factors that make infants more at risk are that they have a high fluid intake in relation to their body weight, and that the water used to make up proprietary baby foods may be decreased in volume by repeated boiling, so increasing nitrate concentrations.

4.6. The link between water containing high levels of nitrate and infant methaemoglobinaemia was first recognised in 1945([48]). Since that time, some 2,000 cases have been reported world-wide, mainly in the period up to 1960. In the USA there have been about 350 cases of which 41 were fatal. In Europe, about 1,000 cases have been reported of which about 80 were fatal. The disease is extremely rare in the UK where only 10 cases have been recorded in the past thirty years, one of them fatal. It appears that wherever methaemoglobinaemia and the factors contributing to it have become widely known, the condition has become rare and fatalities have decreased to vanishing point.

Methaemoglobinaemia and water standards

4.7. In the great majority of those cases of methaemoglobinaemia where the nitrate concentration of the water was known, the levels greatly exceeded 100 mg of nitrate/l (22·6 mg of nitrate-nitrogen/l)*. It is, however, difficult to obtain reliable data on this point, as in the original instances reported (see paragraph 4.6) many of the waters containing high nitrate concentrations (often obtained from private wells) were also contaminated with bacteria. In many of the cases, samples of water were not collected for analysis for weeks or months after the disease was diagnosed, during which time the nitrate levels may have changed considerably. Moreover, other dietary sources of nitrate, such as vegetables, were usually not measured.

4.8. On the basis of the data that had become available in the early 1960s, a limit of 45 mg of nitrate/l was set in 1962 in the drinking water standards of the US Public Health Service, with a requirement that where the limit was

*Nitrate levels are commonly expressed either as the concentration of nitrate ion (NO_3^-), or as the concentration of the nitrogen in that nitrate (NO_3^-N). Since the atomic weights of nitrogen and oxygen are, respectively, 14 and 16, the molecular weight of NO_3^- is $[14+(3\times16)]=62$. Hence, 100 mg of nitrate/l corresponds to $100\times\frac{14}{62}= 22{\cdot}6$ mg of nitrate-nitrogen/l.

exceeded the public should be warned by health authorities of the potential dangers for infant feeding and informed of alternative and safe sources. This limit was also adopted by the World Health Organisation (WHO) in the 1960s. A subsequent review of the position, in the light of the almost complete absence of further cases of methaemoglobinaemia in infants, led the WHO to recommend some relaxation of the limits in the second edition of its European Standards for Drinking Water (1970). The limits recommended were:

recommended levels of less than 50 mg of nitrate/l;
an *acceptable* range from 50 to 100 mg/l;
and levels above 100 mg/l *not recommended.*

The WHO recognised that if water in the "acceptable" range is otherwise chemically and bacteriologically satisfactory, it may not give rise to trouble but advised that physicians in the area be warned of the possibility that infantile methaemoglobinaemia may occur. However, the earlier limit of 45 mg of nitrate/l, more stringent than the European Standards, was maintained by the WHO in the third edition of its International Standards for Drinking Water (1971). The international standard needs to take account of areas of the world where ambient temperatures, and hence the ingestion of liquids, are higher than in Europe and where infantile infections are more common.

4.9. The WHO European Standards referred to above are still current. It appears, however, that there has been some hardening of opinion since 1970 in favour of tighter limits. A WHO European Working Group on health hazards from drinking water, which met in September 1977, proposed the adoption of 50 mg of nitrate/l as the maximum acceptable concentration for infants at risk from methaemoglobinaemia. Since the concentration of nitrate in water is only one factor among others possibly implicated in the onset of methaemoglobinaemia—for example, low standards of hygiene in the water supply and the home, as well as an inadequacy of dietary constituents such as vitamin C, appear to increase the likelihood of the condition—the Group felt it prudent to recommend levels that would apply also to countries where these other factors might play a role more significant than in the UK. The US Environmental Protection Agency in its draft Recommendations for Drinking Water and Health (1977) likewise proposes more stringent limits (45 mg of nitrate/l) and states that this leaves little margin of safety for infants. Furthermore, the EEC Directive on the quality of surface waters intended for the abstraction of drinking water, which came into force in June 1977, sets a mandatory limit of 50 mg of nitrate/l for such waters. A second Directive has been adopted by the Council of Ministers and will become operative when the final text is agreed: the Directive will extend this criterion of water quality to all water supplied for human consumption, including that from groundwater.

4.10. A further feature of the hardening of opinion exemplified by this lowering of maximum permitted nitrate levels in waters emerges from the recommendation by the WHO European Working Group (1977) that, for the general population, nitrate concentrations in the range 50–100 mg/l should be considered borderline and concentrations above 100 mg/l unacceptable. The desirability of setting a limit to nitrate concentrations in drinking water from this wider viewpoint was based on consideration of the possible cancer risk which we consider below. We return to the question of standards and give our recommendations in respect of health hazards in paragraph 4.62.

Nitrate and human cancer

4.11. A potentially more worrying suggestion is that nitrate may be implicated in some forms of human cancer, especially gastric cancer, through the formation of chemical compounds of the classes known as N-nitrosamines and nitrosamides. These N-nitroso compounds, some of which are extremely powerful carcinogens in a variety of animal species, can arise from the interaction of nitrous acid with secondary and tertiary amines, amides, and certain other nitrogen-containing compounds. Nitrous acid is produced in the body from nitrites under acid conditions; amines and amides occur naturally in food. It is, therefore, important to establish whether material amounts of N-nitrosamines occur in food, or are produced under the conditions found in the body.

4.12. It has been reported that N-nitrosamines are widely distributed in the environment, though at extremely low levels. The development of sensitive analytical procedures, particularly the combined use of gas chromatography and mass spectrometry, has enabled these compounds to be detected also in many foodstuffs, particularly those rich in secondary amines (such as fish). The occurrence of N-nitroso compounds has been discussed at conferences sponsored by the International Agency for Research in Cancer([49]).

4.13. In addition to the formation of nitrite from nitrate that occurs naturally in the body, nitrite is often added as such, as a preservative to bacon and to cheese, meat and fish products that are eaten without further cooking. Not only can this be aesthetically pleasing—the oxidation by nitrite of pigments in meats produces methaemoglobin (see paragraph 4.5), which imparts an attractive red colour to them—but it prevents the growth of bacteria that multiply in the absence of oxygen and release harmful toxins. In particular, nitrite inhibits the growth of *Clostridium botulinus* and the germination of its spores. This is important as the organism can cause botulism, a form of food poisoning that is often fatal.

4.14. Whatever the source of nitrite in the body, it will inevitably form nitrous acid under acid conditions such as exist in the stomach and that may arise in the urinary bladder if that is infected with bacteria. It is also possible that some biological process, the nature of which is not yet understood, may effect the interaction of nitrite with secondary amines under conditions of near neutrality. Indeed, there is evidence that traces of nitrosamines are excreted normally with the faeces; these are thought to be formed in the lower gastrointestinal tract([50]).

4.15. The administration of N-nitroso compounds to experimental animals is known to result in the induction of cancers. There is also no doubt that N-nitrosomines can be detected in the stomachs of experimental animals that have been fed concurrently with certain amines and nitrite([51]); furthermore, this feeding regime resulted in the induction of some tumours. However, the number of tumours dropped sharply as the doses of nitrite and amines were reduced and no tumours were induced when nitrate was used in place of nitrite. Nitrosamines have also been shown to be present in the urine of rats which had been fed the amine piperidine together with nitrate and in which bladder infections had been experimentally induced([52]). We may note here that some recent research in the USA([53]) which involved the feeding to rats of large amounts of sodium nitrite in the absence of any added amines, has suggested that nitrite itself may be carcinogenic without the formation of nitrosamines. The report on this work emphasised that the data were only suggestive and that "the results do not permit assigning nitrite a proximate carcinogenic role".

4.16. There is no reason to doubt that N-nitroso compounds would be as carcinogenic to human tissues as they are to those of other animals. The question we have to ask is, therefore, whether the compounds are formed from components of the diet in sufficient amounts under conditions that obtain in normal life. That they can be produced in man was shown by examination of the blood before and after a meal that contained the appropriate constituents([54]) and by examining the urine of patients with infected and uninfected bladders([55]). In the first case, however, the amount was minute; while in the second, the relationship to bladder cancer depended on infestation with parasites that caused bilharzia, which introduces the additional factor of mechanical irritation. Neither of these studies can be regarded as establishing a causal link between nitrosamines and cancer in man.

4.17. Another approach in discerning possible links between nitrates, nitrosamines and cancer is to investigate the incidence of cancer in populations who are known to have an unusually high nitrate intake. There have been a number of studies of this kind. Thus, it was found that the population of Narino in Colombia had a drinking water supply containing high levels of nitrate and also had a high incidence of cancer of the stomach; contrary to the usual experience, the incidence was higher in this population in women than in men([56]). In this country, it was observed that the drinking water in Worksop for a number of years contained over 90 mg of nitrate/l, the highest level in any borough in the UK, and that the mortality from gastric cancer was raised by nearly a quarter in comparison with 9 other neighbouring boroughs of similar social structure([57]). Again, the death rate ran higher in women than in men. However, this study revealed also a raised death rate from gastric cancer in the nearby town of Sutton in Ashfield, although there was no consumption of nitrate above the average. Other facts which weigh against the suggestion that nitrates in water supply play any material part in the production of cancer are that vegetables constitute the principal source of nitrates for most people (Table 4.3a) while the consumption of vegetables tends to reduce the risk of cancer of the stomach rather than to increase it, and that male mortality from gastric cancer in the East Anglian region of Britain, in which the nitrate level of water most often exceeds the recommended level, is lower than in any other region of the UK; female mortality from this cause is lower in East Anglia than in all regions of the UK but one. Moreover, gastric cancer is becoming much less common in almost all countries (including Chile where nitrates have been used as fertilizers on a very large scale—see Table 4.1), despite the world-wide increase in the use of nitrate fertilizers.

4.18. There is thus no evidence that unambiguously associates nitrates and N-nitroso compounds in human tissues or body fluids with carcinoma of any organ in man. More importantly, there is little evidence that N-nitrosamines are formed in significant amounts under physiological conditions. We note that these conclusions are supported by the findings of a WHO Task Group on Environmental Health Criteria for Nitrates, Nitrites and N-Nitroso Compounds which reported([58]) "So far, correlations have not been established that link cancer with exposure to N-nitroso compounds or their precursors . . .". If nitrates do play any part in the production of cancer, it is likely that they do so only in conjunction with many other factors.

TABLE 4.1

Reduction in mortality from cancer of the stomach 22 countries, 1952 to 1973

Country	*Mean death rate for men and women per 100,000 per year: standardised for age* 1952–3	1973	*Per cent reduction*
Finland	53·6	20·9	61
Norway	33·6	14·4	57
USA	12·9	5·6	57
Denmark	26·1	12·5	54
Switzerland	33·6	15·9	53
Sweden	26·5	12·7	52
Israel	24·3	11·7	52
Canada	19·4	9·8	49
Australia	19·4	10·0	48
Netherlands	31·1	16·4	47
France	21·4	12·2	43
German Federal Republic	37·6	21·5	43
Austria	43·5	25·1	42
Belgium*	26·8	15·5	42
Scotland	25·7	15·9	39
New Zealand	17·4	10·8	38
Northern Ireland	24·6	15·3	36
England & Wales	22·3	14·9	33
Ireland	23·9	16·1	33
Italy	29·7	21·6	27
Chile*	58·7	43·5	26
Japan	51·6	45·5	12

*Initial date 1954–5.

Sources of nitrate in the diet

4.19. If a possible risk of cancer has to be taken into account, it is important to know the contributions to the total intake of nitrate made by the various components of the normal diet. Nitrate is present in all plants and consequently vegetables are an important source of nitrate in the diet; high concentrations are found in some vegetables. For example, leafy crops such as spinach and lettuce and, among root vegetables, beet and turnips tend to be rich in nitrate. Other sources are those foodstuffs to which nitrate and nitrite are added as a preservative or a curing agent; these include ham, bacon, corned beef and certain types of cheese. We have commented earlier that it is the intake of both nitrate and nitrite which is of interest but since most nitrite is derived from the conversion of some of the nitrate in the diet after ingestion we have, for simplicity, referred principally to the latter in the following paragraphs.

4.20. Many measurements have been made of the nitrate content of individual foodstuffs over the years and the data that are available in the scattered sources show wide variations. It is known that there is great variability in the nitrate content of vegetables. Nitrate concentrations in plant tissues would be expected to bear some relationship to the availability of nitrate in the root zone and hence to the amount of fertilizer N applied but environmental and physiological factors can mask the effects of differing rates of fertilizer application and it is possible for the nitrate concentration in a plant to change as much as two-fold within a day([59]). Thus the results of analyses reflect the variations in the manner of cultivation, harvesting and storage together with varietal differences. Table 4.2 gives typical European

TABLE 4.2

Reported values for the nitrate content of some fresh Vegetables (mg/kg fresh wt)

Vegetable	*Reference*	*Mean Value*	*Range*
1. Cabbage	3	—	30–580
	4	317	158–475
	5	—	200–450
	6	200	35–484
2. Cauliflower	1	254	(56)*
	4	53	–
	6	66	40–89
3. Spinach	1	2220	(375)*
	4	—	1600–2353
	6	1892	310–3809
4. Carrot	1	72	(56)*
	3	—	80–320
	4	101	18–98
	5	—	286–600
	6	66	39–88
5. Potato	2	22	0–44
	3	40	30–70
	4	104	34–143

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*Standard Deviation: the reference does not quote the range.

and N. American data for fresh vegetables; a similar picture is obtained from analyses of frozen and canned produce([60]). As far as we can ascertain there has been no significant upward trend in the nitrate content of vegetables which parallels the substantial increases that have occurred in the total usage of fertilizers.

4.21. In evidence from the Department of Health & Social Security (DHSS) and the Medical Research Council (MRC) on the relative importance of water as a source of nitrate in the diet, we were referred to a table which appeared in a literature survey prepared in 1970 by the British Food Manufacturing Industries Research Association (BFMIRA) for the use of its members; we reproduce this as Table 4.3a. The table covers only two groups of foodstuffs and we were informed by BFMIRA that the table was not intended to be comprehensive and could not now be regarded as accurate in relation to modern food production and patterns of consumption. It appears that the table has acquired a standing that it does not deserve; we have seen the data used in much published work. Clearly, in order to assess the relative importance of water as a source of nitrate, it is necessary to know the contributions of nitrate from other items in the diet. Such a survey should be based on representative sampling and standardised methods of analysis and should take account of the changes brought about by preparation and cooking. We recognise the technical problems involved but, in view of the concern about nitrate that has been expressed to us, we are surprised that no such systematic survey has been undertaken and say more on this matter in paragraph 4.74.

TABLE 4.3a

Calculated intake of nitrate from various sources

Taken from 'The Occurrence of Nitrates and Nitrites in Foods' BFMIRA Literature Survey No 7 (1970)

	Weekly intake	Nitrate p.p.m.	Nitrate intake
Meat purchases	8 oz	500	110 mg
Vegetables (not potatoes)	15 oz	500	210 mg
Water	7 litres	15	105 mg

TABLE 4.3b

See Appendix 7 for further details

	Weekly intake	nitrate content (as NO_3)	weekly intake of NO_3 (mg)
1. Meat Products	370 g	100 mg/kg	37
2. Milk	2·89 l	30 mg/l	87
3. Cheese	110 g	45 mg/kg	5
4. Vegetables	1·12 kg	200 mg/kg	224
5. Potatoes	1·05 kg	60 mg/kg	63
		Sub-Total	416
6. Water	12·5 l	(see para 4.22)	

4.22. In the absence of such a survey and with full consciousness of its limitations, we constructed our own table of nitrate sources, using published data, some data made available to us by the Secretariat of the Steering Group on Food Surveillance and with advice from BFMIRA. We show this as Table 4.3b and give details of its construction in Appendix 7. From it we derive a weekly intake of about 400 mg nitrate from sources other than water. If, for the purposes of a rough calculation, the weekly consumption of water is taken to be 10 litres but the nitrate concentration is taken to vary, the contributions of water to the total nitrate intake appear as in Table 4.4.

TABLE 4.4

Estimated contribution of water to the weekly intake of nitrate in the UK
(It is assumed that the weekly consumption of water is 10 litres)

Postulated nitrate concentration (mg/l)	Total intake in water (mg nitrate)	Total intake in diet (mg nitrate, but see para 4.21)	Proportion derived from water (%)
10	100	500	20
50	500	900	55
75	750	1,150	65
100	1,000	1,400	71
150	1,500	1,900	79

4.23. If the nitrate content of water remains low (at 10 mg/l), less than a quarter of the total consumption would come from water. On the other hand, water containing the WHO maximum recommended limit for infants (50 mg/l) would contribute over half to the total nitrate intake; that total would also be nearly double the intake that was observed with water at 10 mg/l. At the maximum limit of of 100 mg/l that is being recommended for the general population by the WHO European Working Group (1977), the total nitrate intake would be nearly three times that observed with water at 10 mg/l and water would now contribute seven-tenths to that total. Although we know of no evidence that water containing nitrate at this level is harmful to adults, it would be prudent to bear in mind that continued rises of nitrate in water might not be free from risk. Since the mechanism of formation of a N-nitrosamine appears to involve the interaction of one molecule of an amine with (in effect) 2 molecules of nitrite([61]), the likelihood of forming N-nitrosamines could be proportional to the square of the nitrate concentration. A three-fold rise in that concentration might therefore increase the chance of forming N-nitrosamines in the body by nine-fold.

4.24. In sum, there appear to be two reasons for requiring a limit to the nitrate content of water: first, the risk of causing methaemoglobinaemia in bottle-fed infants and, second, the possibility that nitrates in the diet may contribute to the formation of chemical compounds in the body that cause cancer. The nitrate content of water is only one factor in determining the occurrence of the former disease and there is no evidence to suggest that it has been a problem in countries like Britain with water supplies containing up to 100 mg nitrate per litre. The second possibility is, in theory, feasible and could be considered an argument in favour of diminishing the nitrate content of water to the lowest possible level. Nitrates are, however, an unavoidable component of the diet. They have been and continue to be, consumed throughout the world in large amounts and the evidence that they may contribute to the production of cancer in man is weak and contradictory. Most notably, the type of cancer which, it has been thought, is most likely to be related to the consumption of nitrates is becoming progressively less common with the passage of time. But any tendency for the level of nitrate in water to increase must certainly be kept under close observation. Therefore, we discuss in the paragraphs that follow the changes that have occurred in the nitrate levels of both surface and ground-water and the contribution that the use of nitrogen fertilizers may be making to them. We also consider the options that are open to water authorities should it be considered desirable to lessen the intake of nitrates by infants or by the general population.

Nitrate in water supplies

4.25. Many sources contribute to the nitrate burden of water. The principal route by which nitrate reaches both surface water and groundwater* is by leaching from the land. Inorganic fertilizers, the decay of organic matter in the soil, animal wastes and sewage sludge or effluent applied to land, all contribute to this. Effluent from some sewage treatment works and from septic tanks is discharged directly on to permeable strata and percolates to groundwater. Sewage effluent discharged to rivers is a major source of nitrate also in surface waters. Other sources are industrial wastes, rainfall, soil that is eroded by water or carried by the wind to water bodies and excreta dropped into water by animals. Annual leaf-fall and plant debris carried by the wind are important sources of nutrients to bodies of water with large surface area and small flow. Plant nutrients may also reach water directly as seepage from silage clamps or from the washing and processing of crops in farms or factories. Many of these sources are diffuse in character and their contributions to the nitrate content of water are inherently difficult to assess. Others, such as sewage effluent and industrial wastes, arise from "point" sources and their contributions can be more readily estimated.

4.26. The nitrate standards to which UK water authorities have been working in the past are those suggested by the WHO, as described in paragraph 4.8. We emphasise that, at present, most water authorities are able to keep within the "recommended" limit of 50 mg nitrate/l. A report by the British Waterworks Association (BWA) (the predecessor of the NWC), based on a survey conducted in 1970, showed that for Wales, Scotland and Northern Ireland there were no problems in supplying water with nitrate content less than the "recommended" level. For England, the survey covered 173 water undertakings and indicated that, for 142 of these, all sources had nitrate levels less than 50 mg/l. Of the remaining 31 undertakings, 13 had one or more sources where this level was sometimes exceeded but where the annual average was less than this figure. Of the same 31 undertakings, 22 had sources with annual average nitrate content greater than 50 mg/l, including one undertaking with two sources showing an average concentration equal to the "acceptable" level of 100 mg/l. These data relate to sources and in most cases where sources with nitrate content above 50 mg/l were used, the water was mixed with water

*Groundwater is the term used in the water industry to define water held underground in porous geological strata. Such water-bearing formations are called aquifers.

of lower nitrate content from other sources before supply to consumers. There were in all about 60 sources which either continuously or intermittently exceeded the "recommended" limit of 50 mg nitrate/l. A more recent estimate([62]) suggested that in 1976 the number of such sources had risen to over 100. We comment in later paragraphs on the lack of comprehensive information on nitrate levels in public supply sources and we have formed the view that it would be timely to repeat the survey carried out by the BWA. We refer further to this survey in paragraph 4.64.

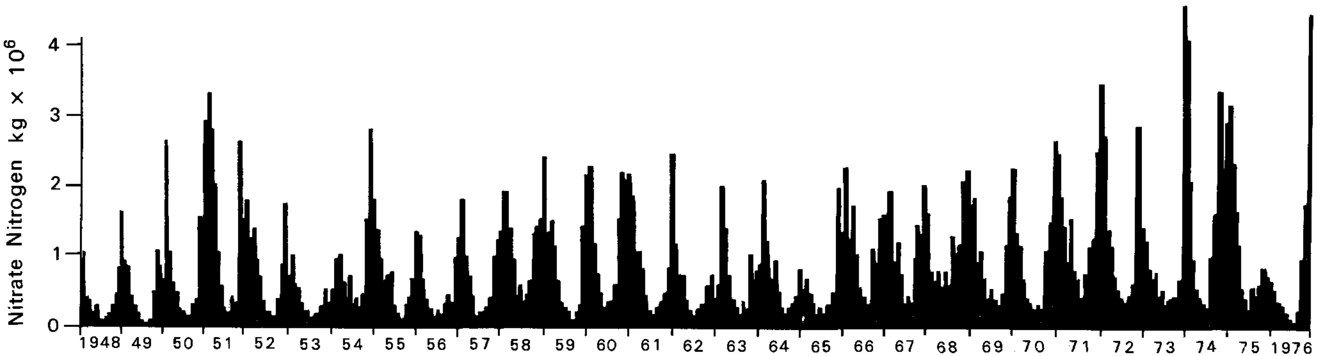
4.27. The supply of water with nitrate content below the "recommended" limit does, however, pose problems for a few water authorities. The Anglian Water Authority, in particular, has difficulty in meeting this recommendation. Groundwater contributes about half of this Authority's supply and one half the water abstracted from this source consistently contains more than 50 mg nitrate/l. We referred earlier (paragraph 4.9) to the EEC Directives relating to water intended for human consumption which set a mandatory limit of 50 mg nitrate/l. Both Directives, however, make provision for waivers to be granted by national governments to cover exceptional conditions, including situations where the limit is exceeded as a result of natural enrichment of the waters.

Rivers

4.28. Nitrate levels in rivers are affected by nitrate concentrations in any aquifers that feed them but in most rivers discharges of sewage effluent and land run-off or drainage have a greater effect. The relative contributions from sewage and land drainage can be estimated by nutrient budget studies of particular river systems and their catchment areas. Studies by the Water Research Centre (WRC)([63]) suggest that, in England, 40 to 50 per cent of nitrate from these two sources in rivers is derived from treated sewage and 50 to 60 per cent from land drainage. Clearly these are average figures and the proportions contributed by the two sources to a particular river system will vary widely depending whether the catchment is primarily agricultural land or whether it includes large urban and industrial areas.

4.29. Nitrate concentrations in rivers vary considerably throughout the year and with climatic conditions. This is illustrated in Figure 4.1 which shows the variation in the nitrate-nitrogen load of the River Thames at Walton over the period 1948–1976. The nitrate contribution from sewage treatment works remains fairly steady throughout the year whereas that from land run-off depends on rainfall and is greatest when flows are high. The high nitrate loads in winter months, which are apparent from the figure, must come from the land. The nitrate concentration in a river depends on both the load and the flow and high concentrations can arise either when the flow is high, with a resultant major contribution from the land, or when the flow is low and there is reduced dilution for sewage effluents. Under suitable conditions, nitrate concentrations may be reduced by natural denitrification, that is, the conversion of nitrate to gases (chiefly nitrogen which is returned to the atmosphere) by bacteria present in soil or water: such conditions also favour the growth of

Figure 4.1
Nitrogen Loads in River Thames (at Walton)



SOURCE: Thames Water Authority

other micro-organisms, which remove nitrate from water and use the nitrogen in building their cell components. Thus, in the drought of 1976 when flows were unusually low, water authorities encountered few problems with nitrate levels in surface water supplies because of increased microbial activity brought about by the high temperatures. Problems arise when such long, dry periods are followed by prolonged rain which leaches out much of the increased amounts of nitrate stored in the soil. The nitrate concentrations in sewage effluent can be reduced by water authorities by treatment at the sewage works. Such a treatment process has been developed by the Thames Water Authority, in co-operation with the WRC, at the Rye Meads works which feeds into the River Lee. There is, however, little that these authorities can do to control nitrate concentrations from land run-off when flows are high, other than to restrict abstractions at such times.

4.30. Because of the variability of nitrate concentrations, especially in surface waters, it is difficult to establish reliable trends. However, there are indications of an upward trend in many rivers. The changes in concentrations that have occurred in the River Thames at Walton and in the River Avon at Evesham are shown in Figures 4.2 & 4.3. (It should be noted that the Avon is not used directly for water supply on the reach to which Figure 4.2 relates.) The NWC have supplied data that appear to show a definite upward trend in the nitrate load of several other important water supply rivers. The trend is not, however, apparent in all rivers; a survey of 17 rivers in England([64]) for the period 1953 to 1967 showed increases in mean annual nitrate concentrations for six of the rivers, a reduction in concentration for one and, for the remainder, no significant change. There appears to be a lack of data on which to establish a synoptic view of trends. Records are incomplete over the retrospective period of 20 to 30 years that needs to be considered and, where they exist, there may be doubt about the methods of analysis used and the comparability of the figures. With the increasing concern about nitrate in water, the levels are now being carefully monitored by the water authorities.

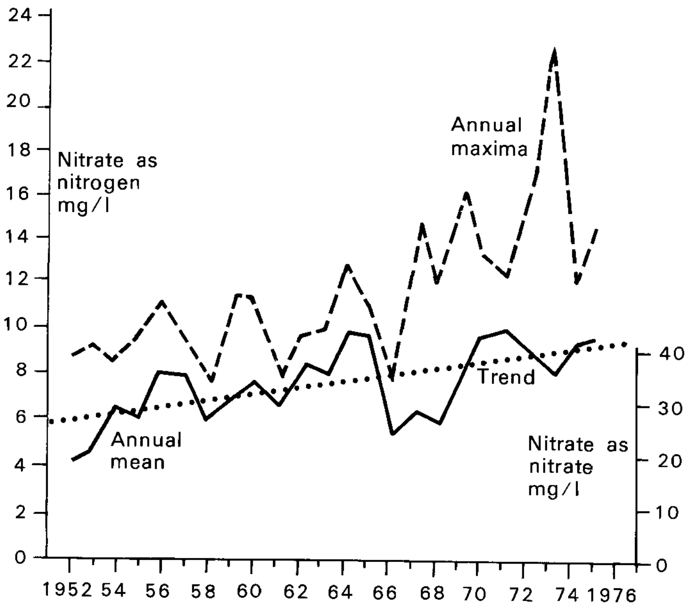
Groundwater

4.31. About 30 per cent of public water supplies in England and Wales are taken from groundwater and in some areas, eg in parts of East Anglia, groundwater is the main source. As in some surface waters, nitrate concentrations have risen in some groundwater supplies. It appears, again, that the data are not available to give a very systematic picture of trends but some information is given in Table 4.5 for the two principal water bearing strata in the UK—the Chalk and Triassic Sandstone aquifers. The location of these outcrops is roughly indicated in Figure 4.4 (which also shows the sites of WRC investigations of nitrate levels).

4.32. Future trends are difficult to predict as they depend to a large extent on understanding the mechanisms involved in the movement of nitrate to underground supplies and on measurements of concentrations within the water bearing strata. Nitrate concentrations through the saturated and

Figure 4.2

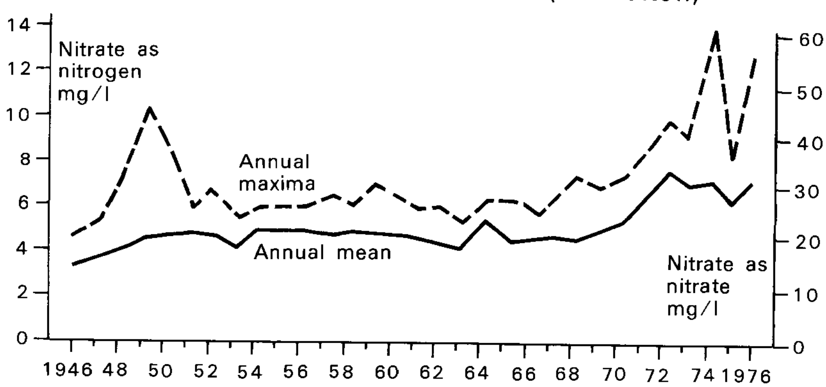
Nitrate Concentration in River Avon (at Evesham)



SOURCE: Severn Trent Water Authority

Figure 4.3

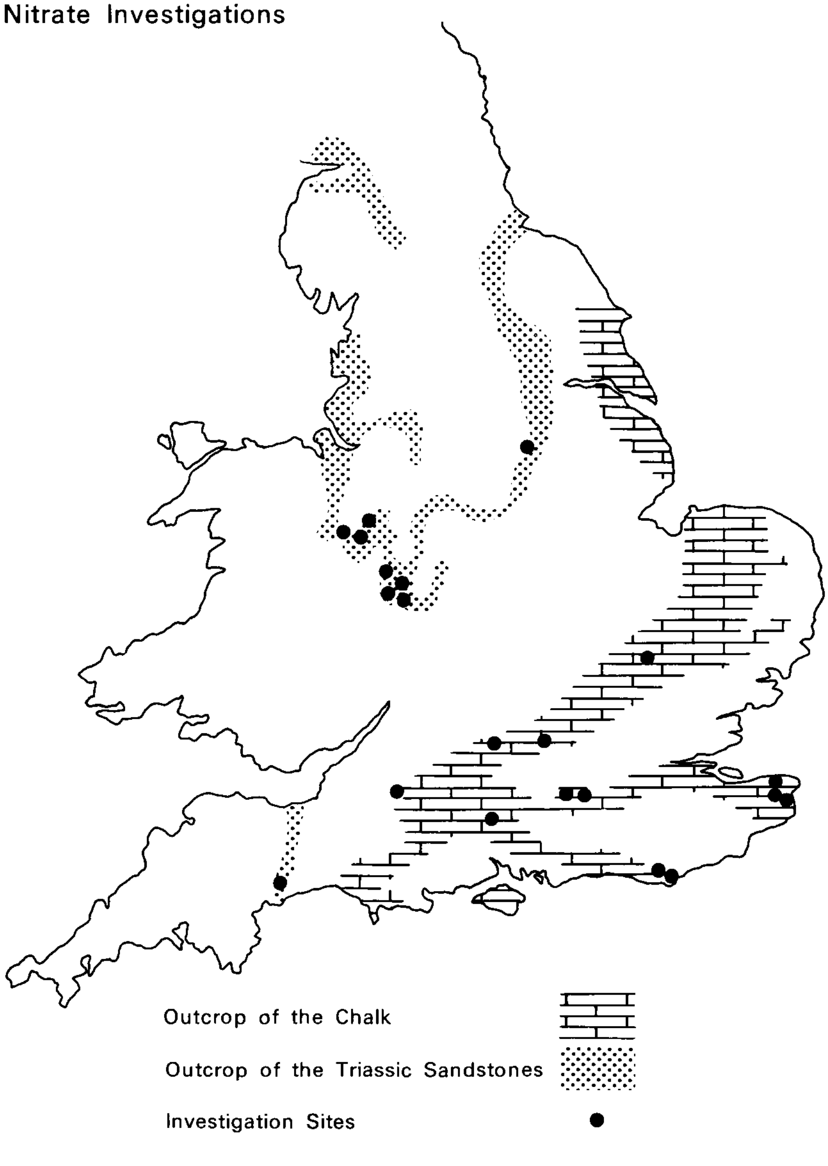
Nitrate Concentration in River Thames (at Walton)



SOURCE: Thames Water Authority

Figure 4.4

Simplified Geological Map of England and Wales, showing the Outcrops of the Major Aquifers and Sites of WRC Nitrate Investigations



SOURCE: C.P. Young E.M. Gray Water Research Centre Technical Report TR 69 (1978) p.7

TABLE 4.5

Observed nitrate trends in the Chalk and Triassic Sandstone aquifers over periods of not less than 10 years

Aquifer	Number of observed wells	Percentage of total showing:		
		Significant rise	No change	Significant fall
Chalk	92	14	76	10
Triassic Sandstone	161	51	40	9

Source: Report of the Central Water Planning Unit: Nitrate and water resources with particular reference to groundwater (1977).

unsaturated zones* of aquifers are now being investigated by the WRC, the NERC Institute of Geological Sciences (IGS) and by some water authorities, at various sites. Analysis of pore water extracted from rock samples drilled from different depths yields "nitrate profiles" of the kind shown in Figures 4.5, 4.6 and 4.7.

4.33. The dependence of the nitrate profile on the kind of agriculture practised is suggested by these figures and we comment further on this point later. Investigations of this kind have shown that very high levels of nitrate, exceeding the maximum acceptable level set by the WHO, exist in pore waters of the unsaturated zone of aquifers below intensively cultivated agricultural land. The question arises whether nitrate movement through the zone is represented by a continuing downward movement of the profile, or whether the profile reflects characteristics of the rock structure. The possibility that such high nitrate concentrations may migrate to the saturated zone, and thus to underground water supplies, gives cause for concern.

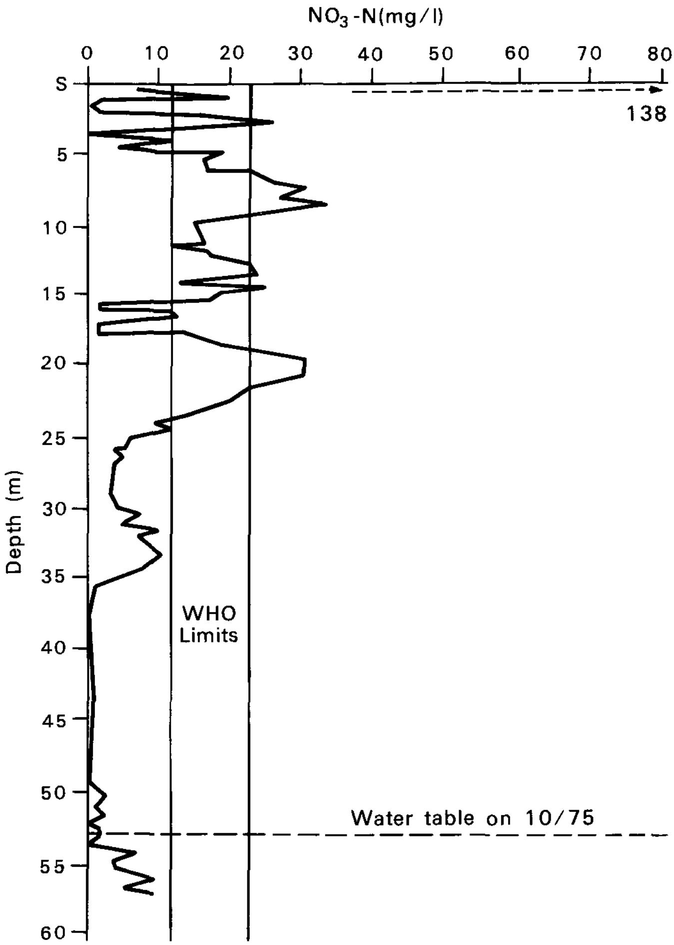
4.34. Elucidation of the mode and rate of movement of nitrate in the unsaturated zone is a principal object of current investigations. Water moves through the zone in two ways: movement is rapid through cracks and fissures in the rock whereas seepage through the pores is slow. Some earlier work suggested([65]) that the movement of pore water forms the major part of the total downward flow. Studies by the WRC at some sites on Chalk([66]) sought to match the observed nitrate profiles with computed profiles using meteorological data and data on past land use and fertiliser application. This work indicated a downward rate of movement of nitrate of between 0·8 and 1·1 metres per year. There appeared to be corroboration for this result from measurements of the tritium† content of pore water at different depths. These were interpreted as indicating that 85 per cent of the total downward

*The unsaturated zone of an aquifer is that between the land surface and the water table in which the pores and fissures are only partially filled with water. The saturated zone is that below the water table.

†Tritium is a radioactive isotope of hydrogen which can combine with oxygen, or with hydrogen and oxygen, to form tritiated water. Traces occur naturally in the atmosphere but its concentration was markedly increased during the period 1958 to 1964 by releases from nuclear bomb tests. The tritium content of rainfall since 1958 has a distinctive pattern and by relating this to the observed tritium profile in the unsaturated zone, deductions can be drawn about the rate of water movement.

Figure 4.5

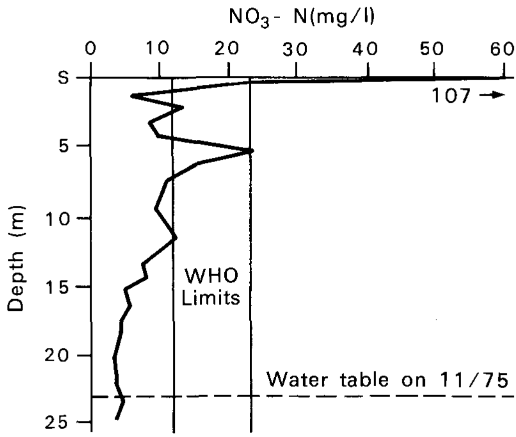
Nitrate Profiles in Chalk
Below Fertilized Arable Land with Temporary Grass Leys



Date of Sampling: October 1975

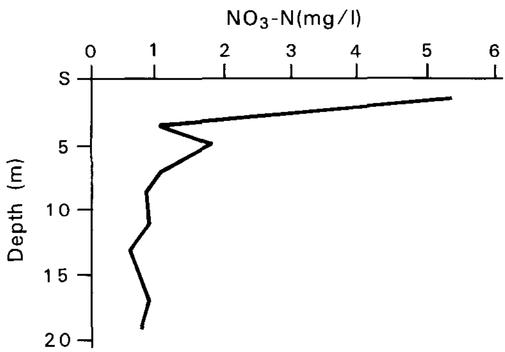
SOURCE: Water Research Centre Technical Report TR69: Nitrate in Groundwater

Figure 4.6
Nitrate Profiles in Chalk
Below Fertilized Long Term Grass



Date of Sampling: November 1975

Figure 4.7
Nitrate Profiles in Chalk
Below Unfertilized Long Term Grass



Date of Sampling: March 1975

SOURCE: Water Research Centre Technical Report TR69: Nitrate in Groundwater movement takes place slowly throught the pores at a rate of roughly 1 metre per year. Such a slow rate of movement would mean that nitrate may take 20—30 years to reach the groundwater, with the implication that groundwater supplies have yet to reflect the doubling of inorganic fertilizer use that occurred in the 1960s. This possibility has led some writers on the subject to refer to a massive "time bomb" of nitrate which will eventually affect water supplies.

4.35. However, there is still much uncertainty on the matter. With regard to tritium tests, other factors have been adduced([67]) that would make the observed levels compatible with relatively rapid flow through joints and fissures as the primary means of water movement through the unsaturated zone. It has been suggested that such flow could also give rise to a slow downward migration of nitrate and other solutes by a process of continuing exchange of solutes between mobile and pore water. The assumption that nitrate moves at the same, slow rate as tritium has been put in question by experimental work at the ARC Letcombe Laboratory([68]) in which nitrate and tritiated water were leached through columns of soil or chalk and in which it was found that nitrate moves more rapidly than the tritium. Other factors could operate to reduce the eventual nitrate levels in groundwater. The nitrate in stored surface water decreases with time through natural biological processes which use up nitrate.There is the possibility that these processes could operate during the passage of nitrate through unsaturated and saturated zones of aquifers and, if this were so, a slow passage over a period of years might be an advantage.

4.36. The work of the Letcombe Laboratory referred to above has been widely interpreted as indicating that nitrate now in aquifers largely reflects leaching from the surface soil in the relatively recent past, and thus as refuting the view that the increased use of fertilizers in the last two decades will cause corresponding future increases in the concentration in groundwater. This conclusion was indeed expressed by the ARC in its Annual Report (1976–77), in a brief description of the Letcombe Laboratory experiment. The Council acknowledged to us, however, that its view on the matter had been influenced by other work, not least the fact that at some sites the nitrate level in groundwater is known rapidly to reflect recent rainfall, and that the point could not yet be regarded as having been conclusively settled. The scientific consensus, including the ARC, is that, in general, the processes controlling the migration of nitrate to groundwater are not understood and that further work is needed to establish the importance of the modes of nitrate transport to underground supplies. We comment in later paragraphs on research programmes and requirements.

Nitrate levels and agricultural practice

4.37. The upward trends that have been observed in the nitrate concentrations of some surface waters and some groundwater have been widely attributed to the great increases that have occurred in the use of inorganic fertilizers in the period since the second world war. The connection between nitrate levels and fertilizer use is not, however, a simple one. Loss of nitrate by leaching is inseparable from agricultural activity. In undisturbed plant communities there is very little loss, the input of nitrogen from rainfall and natural fixation being roughly balanced by the amounts of nitrogen taken up by plant growth. However, cultivation of the soil greatly increases the mineralization of organic matter into nitrate, and hence the availability of nitrate for leaching. Large amounts of nitrate are released, for example, when grassland is converted to arable. Atmospheric nitrogen that is "fixed", i.e., converted to ammonia by the action of micro-organisms that are either free-living in the soil or inhabit the root nodules of leguminous crops, is just as liable to be leached after harvesting as is nitrogen from other sources. Considerable losses may occur when leguminous leys* are ploughed since the large amounts of nitrogen in the root system nodules are readily mineralized to form nitrate.

4.38. Losses of nitrate and other nutrients from land subjected to different cropping regimes have been extensively studied by monitoring of drainage water from particular land areas and by lysimeter† tests. In broad terms, the amount of nitrate leached from soil is found to depend on three factors: the amount of water passing through the soil, which depends on the balance between rainfall and the water transpired by plants as well as on the water-holding capacity of the soil; the amount of nitrate in the soil whether arising from natural processes or fertilizer; and the extent to which nitrate is taken up by growing crops. Generally, the heaviest losses occur during the late autumn, winter, and early spring when there are few crops to intercept the nitrate released by the mineralization of crop residues and soil organic matter, and when rainfall greatly exceeds losses of moisture by evaporation and transpiration. The pattern is demonstrated by Figure 4.1 which shows the nitrate content of the River Thames at Walton. The losses also depend on soil type, being much larger for light soils than for clay soils. In this context, however, the water authorities commented that the streams carrying the highest concentration of nitrate are those draining highly productive clay soils where there is underdrainage of the land. Indeed, the Thames Water Authority largely attributed the increasing addition of nitrate to rivers from land run-off to the increasing underdrainage of land, although this view is disputed by some of the evidence presented to us. But it does appear that the most important single step that can be taken towards improving the productivity of clay soils is the improvement of drainage. Nitrate losses are much smaller from grassland than from arable land because the roots remain active and able to take up nitrate through most of the year and because the soil is undisturbed by cultivation. Drainage from intensively managed arable land will often have a mean annual concentration of 10–15 mg of nitrate–nitrogen/l with much larger levels for short periods. For grassland that is treated with fertilizer and cut, the average concentration does not usually exceed 5 mg/l. Losses approaching those from arable land can occur, however, where grassland is heavily stocked, from the decomposition of nitrogenous material returned in faeces and urine.

*A ley is temporary grassland, often grown as part of an arable rotation.
†In its commonest form, a lysimeter is a block of soil surrounded by an impermeable material with arrangements for collecting water draining through the base.

4.39. The use of inorganic nitrogenous fertilizers contributes directly to nitrate levels in water if nitrate contained in fertilizer or formed from it is leached out before being taken up by plants. It also inevitably contributes indirectly to nitrate levels by increasing the quantity of organic nitrogen in crop residues, which becomes available to be mineralized in soil organic matter. There is uncertainty about the extent of these contributions. The risk of direct loss of fertilizer by leaching is affected by the timing of application. A small proportion (about 2·5 per cent) of fertilizer nitrogen is applied in the autumn to autumn sown crops, little of which will be taken up by the crops until the following spring. The great bulk of nitrogen fertilizer used on arable crops is applied in the spring during the period March to May, a period when leaching losses are likely to be minimized because of reduced drainage through the soil and greater uptake by crops. Because of the unpredictability of rainfall, however, there is risk of substantial leaching in the spring in localities where exceptional conditions obtain.

4.40. There is some experimental evidence to support the contention that, generally, a relatively small proportion of fertilizer nitrogen is lost by leaching. In a three year study by ADAS([69]) using lysimeters cropped with spring barley, the leachate where no nitrogen fertilizer was applied contained on average the equivalent of 31 kg of nitrate–nitrogen per hectare per year, compared with 44 kg per hectare per year from the lysimeters receiving fertilizer (at the rate of 125 kg of nitrogen per hectare on 1 April each year). These results suggest that only about 10 per cent of the applied nitrate is lost through leaching, although this amounts to about 30 per cent of the total amount of nitrate leached. An estimate based on work in the Netherlands([70]) is that when nitrogen fertilizer is used under the best conditions for efficient uptake it will increase nitrate losses by only about 5 per cent of the nitrate applied. It should be noted that nitrate that is lost by leaching, and which is not therefore available to crops, represents a loss to the farmer, and is thus of concern from the agricultural viewpoint no less than from that of water supply. Research aimed at improving the efficiency of fertilizer use is likely also to be of benefit in lessening the risk of pollution. Current work at the ARC Letcombe Laboratory using ^{15}N labelled* fertilizer in lysimeters, suggests that leaching may remove on average from 2 to 5 per cent of the fertilizer applied to grass swards.

4.41. That agriculture affects nitrate levels in water is clear although, as we have indicated, it is difficult to ascertain how far such effects may be attributed directly to the great increases that have occurred in fertilizer use. Investigations of the kind described in paragraph 4.32 have given incontrovertible evidence of the connection between modern, intensive arable farming and nitrate levels in the unsaturated zone of aquifers. There is no doubt that land use (that is, the nature of the agriculture practised, rather than fertilizer use looked at in isolation) is a major factor influencing nitrate losses to water. Indeed, it has been suggested that the observed increase in nitrate levels in some ground-water supplies may reflect releases that stemmed from the large-scale plough-

*^{15}N is a non-radioactive isotope of nitrogen which is used for tracing purposes.

ing of grassland during the Second World War. The amount of arable land in the country has been much more stable since 1945 but if nitrate does take a few decades to pass through some strata to aquifers, such delayed effects could occur. However, the increases that have occurred in nitrate levels cannot be attributed generally to such long-delayed effects. Such effects would not explain the increasing nitrate levels in some surface waters, which rapidly reflect seasonal variations in nitrate losses, or in some aquifers where recharge from surface waters occurs quickly. Nor would they explain the increasing nitrate levels in areas which have remained predominantly arable. The striking parallel between the rising trends in the use of inorganic fertilizer and in nitrate levels leaves us in no doubt that increased fertilizer use is a major cause. But the connection between these trends is complex and it is by no means clear what effect a reduction of fertilizer use would have on nitrate levels. We return to this point below.

Approaches to decreasing the nitrate content of drinking water

4.42. Whether or not there is a "nitrate time bomb" waiting to go off, it is evident that some increase in the nitrate content of many water supplies must be anticipated and it is conceivable that groundwater in some areas will come to contain nitrates in excess of 100 mg/l. The water authorities will, therefore, need to consider the best strategy for reducing the nitrate levels should it prove necessary to do so. In principle, this can be achieved either through action of the water authorities themselves or through alterations in agricultural practice; such alterations might be reductions in fertilizer use or the use of techniques to reduce nitrate losses. We consider below both alternatives.

Action by water authorites

4.43. If action is required solely to avoid the risk of inducing methaemoglobinaemia in infants, one course is to supply low-nitrate bottled water for infant feeding when necessary. Three water authorities have supplied bottled water on a small scale and several made preparations to do so in anticipation of high nitrate concentrations following the 1976 drought, in some cases by arrangements with dairies to bottle water. One authority purchased and installed its own bottling plant; another arranged for a supply of bottled water to be available for collection at clinics or other notified places. These arrangements were not needed on the scale provided for but they enabled some assessment of costs to be made. Water delivered four times weekly by a local dairy using its own bottling plant was found to cost 6·7p per pint (11·7p per litre). Costs could be higher for daily deliveries in some areas and somewhat lower for a large scale operation using purchased plant.

4.44. Arrangements for the supply of bottled water could prove advantageous in enabling the intake by infants of other substances (for example, lead) in drinking water to be controlled should the need arise in particular areas. On the other hand, the question of costs apart, the water authorities are concerned that such arrangements could lead to a loss of confidence by the public in the quality of water supplies. Moreover, there would be considerable practical difficulties in providing a large-scale service; the Thames Water

Authority expressed the view that it would be virtually impossible to undertake the supply of bottled water low in nitrate to all bottle-fed infants in London with a high degree of certainty in coverage. (Six million consumers are involved with an estimated 50,000 infants.)

4.45. An alternative approach is to maintain nitrate levels in drinking water supplies below some approved limit. It is normal practice for water authorities to seek to provide water containing less than 50 mg of nitrate/l, which is the quality recommended by WHO for consumption within Europe. For the most part they are able to do this by mixing supplies from different sources when necessary. We have noted (see paragraph 4.28) that the amounts of nitrate in water derived from sewage can be diminished by treatment at the sewage works but this does not, of course, affect nitrate derived from the land, the amount of which can be lessened only by treatment of water abstracted for supply. In 1973, the DOE, recognising the increasing difficulty of some water authorities in meeting the limit for nitrate content, commissioned studies of possible treatment methods by the WRC.

4.46. Various methods are available. Nitrate can be removed by ion exchange processes (similar to those used in water softeners) although these have the disadvantage that they require periodic regeneration, usually with brine, which presents disposal problems. The natural process of denitrification through bacterial action can be harnessed in a biological treatment method. The method requires a source of carbon for the organisms to utilise, for which methanol is the most attractive possibility. Because of its toxicity, however, methanol could be employed only if it were entirely used up in the process; it might be possible to use ethanol, though at higher cost. Neither of these processes is yet fully proven, although both have been developed to the pilot plant stage by WRC in conjunction with the Thames and Anglian Water Authorities. These Authorities have, respectively, plants of the bacterial reduction and ion-exchange types under trial. Another procedure that could be used for nitrate removal is that of reverse osmosis*. This offers some operational advantages but seems likely to be more costly. Finally, there is the possibility of lowering nitrate levels by making more use of the natural consumption of nitrate by living organisms that occurs when water is held in storage reservoirs. This process is temperature dependent and the rate of nitrate removal, effected largely through the growth of algae, is difficult to predict. Storage would be required for relatively long periods but this need not be unduly demanding when used in conjunction with surface water abstraction, since the stored water would need to cover only the short periods (usually in later autumn and early winter) when nitrate concentrations in the normal supplies are high. Cost estimates of the various options for nitrate removal have been made by WRC and are set out in Table 4.6.

4.47. The figures given in Table 4.6 may be compared with the average cost of conventional water treatment, which is 15p per cubic metre. It has

*Reverse osmosis is essentially a highly efficient form of filtration. Impure water is forced through a membrane which prevents the passage of molecules of soluble impurities.

TABLE 4.6
Costs of nitrate removal per cubic metre of water supplied

	pence per cubic metre supplied
ion exchange	2.0 to 2.5
biological denitrification	0.8 to 1.0
reverse osmosis	5.0 to 6.0
storage—5,000 cu m for 28 days	1.7
for 6 months	6.0
500,000 cu m for 28 days	0.4
for 6 months	1.4
blending	3.8 to 9.0

At November 1976 prices; with an apportionment for capital costs; land costs are taken to be £650 an acre, the average value in the range published by MAFF on the basis of ADAS/Agricultural Mortgage Corporation data: land costs in the Anglian Water Authoriy's area, where the nitrate problem is greatest, are likely to be at the upper end the range.

been estimated that if all sources regularly exceeding 50 mg of nitrate/l were treated by use of an ion-exchange process, the total capital cost would be £45m and the annual running costs £15m. If those sources that occasionally exceed 50 mg of nitrate/l were similarly treated, the capital cost would double to £90m and the running costs would increase to £20m per year (the proportional increase in running costs being smaller since continuous operation of the plants would not be required). All these estimates are 1976 values. These costs are substantial and clearly the water authorities are concerned that they should not be incurred unless there are incontrovertible grounds for doing so. These authorities are concerned, too, that all reasonable steps should be take to reduce the impact of agricultural practices, particularly the use of nitrogenous fertilizers, on nitrate levels in water.

Action through alterations in agricultural practices

4.48. There is no doubt that the intensification of agricultural practices is a major factor in the increases in nitrate levels that have occurred in some water supplies although, as we have explained, there is uncertainty about how far these increases may be directly attributed to the use of fertilizers. On this latter point, as on others that we have considered during our study, we are conscious of a marked divergency of viewpoint between those agencies concerned with promoting agriculture and fertilizer use and those concerned with water quality and the wider environment. Such divergencies are bound to exist where the facts of a highly complex matter with wide-ranging implications are in dispute; nevertheless, it is important that they should not become ingrained in opposing attitudes that impede concerted action to find solutions.

4.49. Though the extent of the direct loss of fertilizer by run-off or leaching is in doubt, it is clearly desirable from the viewpoints of both the farmer and the environment that the loss should be minimised. Information on the use of fertilizers is provided by the advisory services; this enables recommended application rates to be determined that take account of the needs of the crop, the type of soil, past use and treatment of the soil and previous weather conditions. The advice is based on information obtained in controlled trials carried out by MAFF and other bodies. Data on actual fertilizer usage is obtained from annual surveys that are conducted by the Ministry in collaboration with the FMA and the Rothamsted Experimental Station.

4.50. We were informed by MAFF that the surveys indicate that fertilizer usage is, on average, close to recommended rates on most crops except grass. This conclusion is supported by the figures given in Table 4.7 for four major crops which account for three-quarters of the area and of nitrogen fertilizer usage in England and Wales, excluding grassland. Other agricultural bodies support the validity of these figures.

TABLE 4.7

Average usage of nitrogen fertilizers in 1976 on some important crops compared with recommended rates, England and Wales

	(kg N/ha)		
	Average Usage	Range of Recommendations	Typical Recommendation
Winter wheat	102	0–125 (exceptionally 175)	75–125
Spring barley	78	0–125	100
Maincrop potatoes	177	0–220	180–220
Sugar beet	155	0–150	100

(*Source:* Ministry statistics)

4.51. The view put to us by farming interests is that the high cost of fertilizers provides a sufficient incentive to ensure that they are used efficiently. On the other hand, it has been asserted ([71]) that most farmers do not use fertilizers as efficiently as they should and that many do not seek out or do not heed, the advisory services. The amounts applied should take account of the local conditions that determine how much nitrogen the soil can supply. The risk of water pollution from fertilizers is also increased if fertilizers are applied at the wrong times.

4.52. We understand that the National Vegetable Research Station is experimenting with test kits that would enable growers to assess the nutrient characteristics of their land and thus achieve some quantitative estimate of the amounts of fertilizer needed before any is applied. We recommend that efforts be intensified to develop such test kits for more general use in agriculture.

4.53. A number of techniques are, or may become, available to improve the efficiency of nitrogen fertilizer usage or to reduce nitrogen losses from the soil. Slow release fertilizers, such as sulphur-coated urea, have been developed with the aim of matching the release of nitrogen with the ability of crops to absorb it. A similar effect may be achieved by the use of nitrification inhibitors which are applied to the soil with ammonium fertilizer to slow down its oxidation to the leachable nitrate form. These techniques are still being evaluated and the extent to which they may offer benefits in terms of crop yields and leaching characteristics still appears uncertain. It is difficult, except under closely controlled conditions as in a glasshouse, to match the release of available nitrogen to the needs of the crop. In a dry summer such fertilizers may decompose too slowly and release nitrogen only after harvest when the early winter rain falls on the still-warm soil. Moreover, slow release fertilizers are expensive.

4.54. Another technique for relating fertilizer application to crop needs is by split dressings*. However, there is evidence that, in general and for most arable crops, split dressings offer little advantage in terms of yield over single dressings applied at the optimum time. We would wish extensive leaching trials to be carried out to determine the advantages, if any, of split dressings from the environmental point of view. We understand that research on these lines is currently in progress.

4.55. We have referred earlier to the increasing use of minimum cultivation methods† and direct drilling‡ and we have enquired about the likely effects of these practices from the environmental viewpoint. Studies by ADAS and ARC have shown that soil nitrate concentrations are often decreased under minimum cultivation, so that an increased application of fertilizers is sometimes needed. Because of changes in soil structure produced by the technique, the pattern of water movement in the soil is different; water appears to move more rapidly to greater depths. It is not yet known, however, whether minimum cultivation is likely to lead to more or less leaching of nitrate than from conventionally cultivated land. We note that in 1978 MAFF and ARC started an experiment to test the effects of drainage and methods of cultivation on the nitrogen requirements of the crop. Other work may be necessary to clarify this important aspect.

4.56. MAFF referred in its evidence to the concept of "maximum yield". This term is applied to farming techniques designed to optimise the inputs that affect crop growth and thus to obtain yields much closer to the known potential of the crop than currently are generally achieved. Using such techniques, potato crops of two or three times the national average yield have been grown but similar success has yet to be achieved with cereals. MAFF informed us that maximum yield systems would call for considerably increased dressings of fertilizers but that there was unlikely to be any rapid move towards the introduction of such systems. Nevertheless, the possibility that these methods might be adopted more widely in the future and that this might lead

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*The total fertilizer requirement of a crop may be applied not in a single application or dressing but in several lighter applications or "split dressings" with the aim of matching the nutrient supply with the needs of the growing crop.
†"Minimum cultivation" refers to methods of cultivation designed to eliminate the need for traditional mould-board ploughing thus reducing soil disturbance.
‡"Direct drilling" is a technique whereby seeds are planted directly into undisturbed soil rather than a prepared seedbed.

to a substantial increment in fertilizer use and in nitrate levels in water was one that we felt bound to consider.

4.57. A number of systems of the maximum yield kind have been developed, principally for cereal and potato growing. It appears from our enquiries that the systems currently applied to cereals in fact generally require nitrogen applications similar to those recommended by the advisory services, although one system requires fertilizer application about twice as great as that normally recommended. The systems so far used with potatoes all require nitrogen applications considerably in excess of recommended rates. These systems have not been widely adopted because market forces do not at present make them worthwhile and more experimental work is required.

4.58. The essence of these methods is meticulous attention to the needs of the crops, including the efficient use of fertilizer by applying the optimum amounts at the optimum times. It may well be that because of the discipline these methods entail, there would be little direct loss of fertilizer through leaching or drainage even though considerably greater amounts may be applied than in conventional farming. However, such increased use of fertilizer could lead to increased nitrate losses by the indirect mechanism referred to in paragraph 4.39. Though maximum yield methods appear unlikely at present to be widely introduced, circumstances might change. We therefore think it is important that research should be undertaken to investigate the likely consequences of these methods on nitrate losses and we so recommend.

4.59. We have referred so far to techniques that might reduce the environmental impact of fertilizer use rather than to any real restraints on agricultural operations. We consider now whether there is any case for placing restrictions on the use of nitrogen fertilizers by farmers. Such a case would be strongest in a region such as East Anglia where over half of the public water supply is derived from groundwater which contains high nitrate concentrations. There is evidence that these concentrations are rising and that in large measure, because the area is rural, this can be attributed to changing agricultural practices.

4.60. We asked MAFF to estimate the possible losses from restrictions on agriculture in the outcrop areas in East Anglia where problems exist with groundwater supplies. The results are summarised in Table 4.8. On the assumption that fertilizer use was halved on crops and grass, the net loss (allowing for savings on fertilizer costs) was estimated to amount to about £17m per year. Some indication of the costs of removing nitrate from water has already been given in paragraph 4.46: for the removal of nitrate from groundwater the Anglian Water Authority estimated that capital costs of £10–15m were involved and that the annual running costs would be some £3–5m.

4.61. It must be pointed out that MAFF's estimates are subject to heavy qualification. It is assumed that the existing crop pattern would be maintained despite the postulated 50 per cent reduction in the use of nitrogen fertilizer, whereas it seems likely that substantial changes would be made to off-set the effects of fertilizer reduction. The figure of £17m per year must be regarded as the worst case. However, even allowing for this point, the evidence suggests that, if a reduction of nitrate levels in water were deemed necessary, the costs of achieving this through nitrate removal by the water authority would be less than the costs to the nation of severe restrictions on agriculture. In addition it is known that such action taken by a water authority will work whereas the results of a reduction of fertilizer use are exceedingly difficult to predict. There is no certainty that the postulated 50 per cent reduction in fertilizer use would lead to a worthwhile reduction in nitrate concentrations. Action by the water authority, as compared with action by agriculture, would in this case appear to be not only less costly but more effective. If this were true of East Anglia, we would expect it to hold good for the rest of the UK.

TABLE 4.8

Expected typical losses resulting from reduction in usage of nitrogen fertilizer

	Present rate of fertilizer application*	Expected total gain in yield from fertilizer usage	Loss in yield from 50 per cent reduction in application of nitrogen fertilizer	
	kg N/ha	tonne/ha	tonne/ha	£/ha
Winter wheat	102	2·35	1·17	103
Spring barley	78	1·17	0·58	46
Maincrop potatoes	177	11·33	5·66	311

*Average rates of application in England and Wales in 1976

(*Source:* MAFF)

The above figures of expected yield losses should be compared with possible average total values per hectare of the above crops at present rates of fertilizer use: these values are of the order of £400, £300 and £1,500 for wheat, barley and potatoes respectively. The losses range, therefore, between 15 per cent and 25 per cent.

Recommendations in respect of health hazards

4.62. We return now to the question of the health hazards posed by nitrate in water supplies and to the related question of standards. The WHO European standards described in paragraph 4.8 are still current except in so far as they have been modified by the relevant EEC Directive (see paragraph 4.9). We have noted that a WHO European Working Group has proposed a tightening of standards: namely, the adoption of 50 mg nitrate/l as the maximum acceptable concentration for infants and of 100 mg nitrate/l as the maximum acceptable concentration for the population as a whole.

4.63. So far as a limit is required to reduce the risk of methaemoglobinaemia in infants, we can see no reason to adopt 50 mg nitrate/l as a rigid limit in the UK. There would appear to be a substantial amount of evidence to support this viewpoint. We were informed by the NWC, for example, that in the autumn of 1976 about 300,000 people (including perhaps 3,000 young babies) in the region of the Severn-Trent, Yorkshire, Southern and Wessex Water Authorities received water supplies with nitrate levels of between 50 and 100 mg/l, but no cases of methaemoglobinaemia were reported. The Anglian Water Authority has estimated that about two million people in its region received water supplies with nitrate levels of between 50 and 100 mg/l during the autumn and winter of 1976/77; doctors were warned to look out for cases of methaemoglobinaemia but, again, none was reported.

4.64. Further information was contained in the BWA report to which we referred in paragraph 4.26. A survey conducted in 1970 indicated that there were then a few areas where water with a nitrate content exceeding 50 mg/l was consistently supplied. In one area (the Worksop area of Nottinghamshire) water at that time showed an average level of 100 mg nitrate/l. However, no cases of infant methaemoglobinaemia were reported in the survey. It was also noted in the report that the local Medical Officer of Health and his staff were fully aware of the problem and were keeping a very close watch on infants in the area, but that there had been no signs of ill effects attributable to the exposure of infants to these elevated levels of nitrate.

4.65. We note in passing that the report referred to above was not published; it was, indeed, regarded as confidential, apparently because it was thought that its contents might alarm consumers in areas served by sources with high nitrate levels. We regard this attitude as misguided; apart from other considerations, information of this kind might be exceedingly valuable as a basis for epidemiological work which could contribute to knowledge of the risks posed by high nitrate levels in drinking water.

4.66. In a matter so important as infant health, the need to err on the side of caution is particularly strong. We conclude that, in the present state of knowledge, the UK should continue to work to the existing European Standards: that is, water authorities should where possible supply water with a nitrate level less than 50 mg/l but a supply in the range 50–100 mg/l should be regarded as acceptable, given that physicians in the area concerned are warned of the possibility of methaemoglobinaemia occurring. In view of the significance of the limits to water authorities, however, we consider that further work is required to substantiate these limits under UK conditions. The need for this is apparent in relation to the question of responsibility for the provision of bottled water for infants, on which at present there appears to be some confusion. We were informed by the NWC that while water authorities would accept the need to provide bottled water where a supply exceeded 100 mg nitrate/l, most authorities would be reluctant to accept any obligation to make (and pay for) such provision where supplies were in the range 50–100 mg/l unless there were clear medical evidence that this is essential. On the other hand, we note that the recently published DOE Digest of Environmental Pollution Statistics indicates that where levels exceed 50 mg nitrate/l, health authorities may issue warnings to parents of young infants to use bottled water supplied by water authorities. The position is unsatisfactory and it is important to obtain the information that is needed before a clear policy can be evolved. We comment further on this point in paragraph 4.71.

4.67. Continuing adherence to the WHO European Standard implies a conflict with the EEC Directives relating to water intended for human consumption which set a mandatory limit of 50 mg nitrate/l. The conflict is perhaps more apparent than real since, as we have noted, waivers are allowed to cover special circumstances. On present evidence, we can see no reason why the UK should adopt this limit.

4.68. There appears also to be no basis for setting a more stringent limit at present to nitrate levels in water in relation to a possible cancer risk. We know of no evidence that water containing nitrate at 100 mg/l is harmful to adults.* Nevertheless, the various considerations we have outlined earlier in this chapter, concerning the risks posed by N-nitroso compounds and the possibility of their being formed within the human body, suggest that it would be prudent to reduce the intake of nitrate and nitrite in the diet as far as reasonably possible; and, according to our calculations, (see Table 4.4) water with a nitrate level of 100 mg/l or more would contribute more than seven-tenths of nitrate in the diet. We conclude that nitrate concentrations above this level should be regarded as unacceptable generally, at least until more information on this point is available. On this basis, and on this point, we find ourselves in agreement with the WHO European Working Group (1977).

4.69. The limit of 100 mg nitrate/l, to protect infants, can be achieved by most water authorities without great expense. Should nitrate levels appear to be approaching 100 mg/l, water authorities should be prepared to provide alternative supplies or to reduce the level by one or other of the methods open to them. While we think it would not be in the interests of the country to attempt to control the level of nitrate in water by restricting agricultural practices, we would stress that farmers can help both the community and themselves by adopting methods that minimise the loss of nitrate.

4.70. We do not regard these conclusions as providing more than guidelines for the immediate future. In the absence of more detailed knowledge of the medical effects of dietary nitrate, of the trends in water nitrate, and of the mechanisms by which the levels are affected, it is impossible to make dogmatic recommendations for the long term except that more research is needed. In the next two sections we comment on those problems which seem to need the most urgent attention.

Research on medical aspects of nitrate

4.71. Methaemoglobinaemia is very rare in this country, the circumstances

*We note here that adults with renal failure using home dialysis machines could be affected by nitrate in the water supply. The medical requirements of patients with renal disease should not, however, determine the standards of water purity for the general population. It is the responsibility of the National Health Service to ensure that where necessary water of appropriate standard is made available to such patients.

in which it is likely to arise can be foreseen and appropriate measures can be taken to prevent it. We therefore understand the view expressed to us by the MRC that it is unnecessary to undertake any further fundamental research on this subject. For the reasons given in paragraph 4.66, however, we consider that further investigation is needed in order to substantiate the current WHO European limits under UK conditions. The aim should be to check that the occurrence of methaemoglobinaemia is not being overlooked in areas where water with nitrate level above 50 mg/l is being supplied, and that there are no long term effects from minor degrees of the condition. This is a matter that could be arranged most appropriately by the DOE and DHSS Joint Committee on the Medical Aspects of Water Quality and we so recommend.

4.72. A great deal of research is already being conducted in many countries on N-nitrosamines and human cancer. In the UK, much work has been done and is underway on N-nitrosamine formation and the conditions that determine it, and on the mechanisms of N-nitrosamine-induced carcinogenesis in animals. With regard to epidemiological work, a larger survey than that previously conducted in the UK is at present in progress. This study, mainly funded by DOE, is expected to be completed within about three years and to reveal whether there is any correlation between nitrate in drinking water and gastric and other cancer. In its evidence, the MRC stressed the importance attached to the study, which should define the problem more closely and which might suggest areas for further research.

4.73. The DOE indicated that data are being sought on the health of industrial workers constantly exposed to nitrate. We welcome this and indeed have ourselves sought information on this matter from the fertilizer industry. Two questions are posed: whether workers in the industry absorb an excess quantity of nitrate; and whether there is any evidence of excess cancer risk in such workers. Answers to these questions could be of value for assessment of the risk posed by nitrate to the population in general, especially if they were to show no increased incidence of cancer despite excess exposure. We understand from our enquiries that an epidemiological study is being carried out on workers in the industry but that results will not be available for some time. It appears, however, that there has as yet been no rigorous check on the nitrate intake of those workers exposed to excess nitrate in relation to that of control groups not so exposed, such as might be obtained through urine analysis. We recommend that this work be undertaken.

4.74. We commented in paragraph 4.21 on the lack of data on nitrate intake from items of the diet other than water. There appears to have been little or no investigation of the nitrate content of food as consumed, although substantial changes could take place during preparation and cooking. The solubility of nitrate, for example, suggests that much may be lost to the cooking water, which may be subsequently discarded. On the other hand, nitrate concentration is increased in water that is boiled for a considerable period; this could lead to higher levels in foods such as stews, dependent to some extent on the initial water content. We understand that MAFF, through its Steering Group on Food Surveillance, has contemplated undertaking a study on this matter but that there are no firm plans to do so; clearly the design and carrying out of such an investigation would present difficulties. While we think that our calculations of nitrate intake from the diet and of the relative significance of drinking water in this context (Tables 4.3b and 4.4), are unlikely to be greatly in error, it is important that knowledge on this matter should be placed on a sounder basis. We accordingly recommend that the study should be undertaken.

4.75. Subject to the points made above we are satisfied that, for the present at least, adequate research is being conducted in the UK on the health aspects of nitrate. Extension of research effort could well be required as understanding of the problem of N-nitrosamines and human cancer increases and, depending on what is learned from research on other areas, about probable future trends in nitrate levels in water supplies. The intake of nitrate in the diet cannot be avoided but it is a matter of considerable importance, and a prime aim of research, to find out whether the levels of dietary nitrate determine in any way the risk of gastric or other cancers and, if so, what levels lead to a material risk.

Research on nitrate levels in drinking water

4.76. Our inquiries revealed that a good deal of research was underway on the factors that determine nitrate levels in drinking water. For example work sponsored by MAFF (and which is largely carried out at research institutes of the ARC and of NERC, and by ADAS) is directed to improving understanding of factors affecting the efficiency of fertilizer use, of the nutrient balance of experimental catchments receiving no fertilizer, and of the effects of changes in land treatment. Similarly, DOE has commissioned research on the nitrate pollution of aquifers, the mechanisms that determine nitrate levels in ground-water and the effects of land use practices. DOE is also supporting lysimeter work at the ARC Letcombe Laboratory, in which the movements through the chalk of nitrate from ^{15}N-labelled nitrogen fertilizer are measured, and studies at the WRC on the possible extent of denitrification within aquifers.

4.77. In addition to the work undertaken by the official agencies, much research is being done by the fertilizer industry; this includes studies on the efficient use of fertilizers and of the measurement of leaching losses. Another important area of work concerns the development of models to simulate the sources and movement of nitrate that reaches water supplies, as a basis for forecasting future trends for particular catchments. Although many useful studies of this type have been carried out, eg by the Central Water Planning Unit ([72]), it is clear that more detailed knowledge is needed of the physical, chemical and biological processes that determine the formation and movement of nitrate before such models can achieve the desired predictive value.

4.78. On the evidence we have received we have found it hard to assess whether the total programme of research on nitrate levels in water supplies is adequate and appropriate to the potential importance of the problem. In particular, we have found it hard to discover how the various research projects being undertaken by the numerous bodies involved are related to each other and to any overall research strategy. We are not alone in this: several bodies have presented evidence to us that expressed similar uncertainty.

4.79. Although there appears to be no lack of machinery to ensure co-ordination of research, we were unable to ascertain the thinking on priorities that is a factor in determining the resources applied to different aspects. Such thinking is implicit in the decisions that are made in sponsoring the research but we have not seen it explicitly described. We have formed the view that it would be timely and useful to prepare a "stock-taking" of research on nitrate movements into and out of soils and waters, followed by annual surveys to review priorities and we recommend that this should be undertaken by the DOE/NWC Standing Technical Advisory Committee on Water Quality. In this context, we welcome the setting up of a Royal Society Study Group on the Nitrogen Cycle; the work of this Group will undoubtedly help in collating and assessing the scattered information on the possible risks of damage to water quality posed by nitrogen fertilizers in the various regions of the UK. We would hope that MAFF and DOE will offer all help to the work of the Group and maintain close links with it.

4.80. There are several particular areas where we suspect that further work may be needed. We commented earlier on the apparent lack of a complete picture of the trends of nitrate levels in water supplies. We were assured that the trends are being carefully monitored and we hope that a more satisfactory picture of the position as a whole will emerge. It would seem desirable to try to establish for many more rivers used for potable supplies, the relative contributions of nitrate from sewage effluent and from the land. There may be a need for more catchment studies in areas used for different kinds of agriculture. Finally, we are not convinced that sufficient work is being undertaken on the removal of nitrate by biological activity that may occur in surface or underground water; or on the factors that lead to the autumn peaking of nitrate levels in surface waters.

4.81. These comments relate mainly to work sponsored by DOE and by the water industry. As indicated in paragraph 4.76, some research sponsored by the Agricultural Departments, though primarily directed towards improving the efficiency of fertilizer use, is relevant to the question of nitrate levels in water supplies and thus forms part of the total research effort applied to the problem. We comment in a later chapter (paragraph 8.6), on an apparent gap in the allocation of responsibilities between DOE and MAFF with regard to pollution issues raised by agricultural activities, but the point may be illustrated here with reference to the research programmes of the two departments as they relate to the nitrate problem. The DOE view is that research on polluting effects of agricultural activities is primarily a matter for MAFF and DAFS. DOE research concentrates on the pathways of nitrates in the environment and on the scale and consequences of their contamination of water supplies. For example, with regard to the DOE sponsored studies on nitrate pollution of aquifers, we were informed that the DOE had to take the lead in this work because the provenance of the nitrate in the groundwater is unknown and the connection with agriculture cannot be proven. On the other hand, we were informed by MAFF that the Ministry sees particular advantage in commissioning work that is relevant to the avoidance of pollution *and* (MAFF emphasis) to the improvement of the economics of farming. This is no doubt sensible. But there is a risk that work that should be undertaken on some aspects of agriculture is not done by DOE because it is regarded as a matter for MAFF and not done by MAFF because it offers no obvious benefits for farmers.

4.82. Several examples occur to us that we suspect might fall into this category. These are: research on the effects of the adoption of minimum cultivation and direct drilling in terms of nitrate leaching; research on the effects of split applications of fertilizer; and research on the effects of improved land drainage. Some work is in progress in all these areas though we are not satisfied that it is sufficient. Our concern here, however, is not so much to press for additional work in particular areas as to urge that it should be a clear responsibility of the agricultural departments to promote research on the polluting effects of agricultural practices, whether or not such work appears likely to bring benefits in terms of farming economics.

4.83. We have mentioned research conducted within the fertilizer industry that is relevant to the question of nitrate in water. A point that has arisen in our discussions is whether there is sufficient liaison between industry and official bodies when planning state-sponsored research. It was put to us that in the past there has been a reluctance on the part of commercial interests to co-operate in research programmes aimed at improving the efficiency of fertilizers but that the climate of industrial opinion is changing. We are aware that there are meetings between the FMA and ADAS on specific topics and that the FMA is now represented on the Nitrates Sub-Committee of the DOE/NWC Standing Joint Advisory Committee on Water Quality. However, we consider that benefits could accrue from more formal links being established between the industry and ARC, and that the industry viewpoint could more fully be taken into account in the deliberations of the co-ordinating body concerned with research sponsored by DOE and the water authorities. We were told that the ARC is anxious to establish formal links with industry and would welcome much closer consultation and contact at all levels. The FMA expressed a similar view in its evidence. We therefore recommend that appropriate arrangements be made to these ends.

Eutrophication

4.84. We have so far considered fertilizer use in relation to the problem of rising nitrate levels in water supplies and the possible risks to human health. Nutrients, including nitrogen, that reach surface water from land drainage, sewage effluent or other sources, may have other effects which are important environmentally and which can pose problems for water supply apart from considerations of health. These effects arise through the enrichment of the water by the nutrients, a process known as eutrophication.

4.85. The population of plants and animals in a river or a lake varies both in density and composition according to the nutrient available. Bodies of water can on this basis be broadly classified into three types, those rich in nutrients, those of an intermediate type and those poor in nutrients: the adjectives used to describe these types are eutrophic, mesotrophic and oligotrophic respectively. Rivers rising in high country tend to be oligotrophic near their sources and as they flow from the uplands down through the lowlands to the sea they become more eutrophic because organic debris and soil washes or drains into them from the land through which they flow. Upland lakes generally have the clear water and small populations of flora and fauna characteristic of oligotrophic systems whereas lowland lakes are more eutrophic, with more turbid water containing more intense and varied life. In a freshwater system there is an inevitable trend towards the eutrophic end of the scale as organic debris and silt containing nutrient elements such as nitrogen and phosphorus gradually build up. Thus, in the absence of human intervention eutrophication is a process that takes place naturally but at a very slow rate: human activity accelerates the process greatly. Cultivating and fertilizing land increases the nutrient content of drainage and run-off to water, to which sewage effluent might also be added. The effects of such enrichment are particularly noticeable in bodies of water where there is virtually no flow. Algae flourish on the surface, cutting off light from aquatic plants beneath, which die. The rotting vegetation removes oxygen from the water and this, combined with the elimination of food sources, leads to a rapid decline in the populations of fish and other living creatures. The body of water becomes lifeless and stinks. It is this phenomenon of greatly accelerated enrichment that may be caused by pollution together with the effects of the resulting uncontrolled and excessive plant growth that is now generally associated with the term "eutrophication".

4.86. Eutrophication can thus result in biological degradation of water bodies, with adverse effects on recreation and amenity; the best known case in the UK is the Norfolk Broads where widespread ecological harm and damage to amenity have already occurred. (It should be noted, however, that in the Broads as in some other waterways other factors have contributed to the deterioration, including the increasingly heavy exploitation for tourism and recreation.) The excessive growth of algae in reservoirs can create problems to water authorities by blocking filters and by imparting unpleasant tastes and odours to the water. Eutrophication is also of concern from the conservation viewpoint because of its adverse effects on wildlife populations.

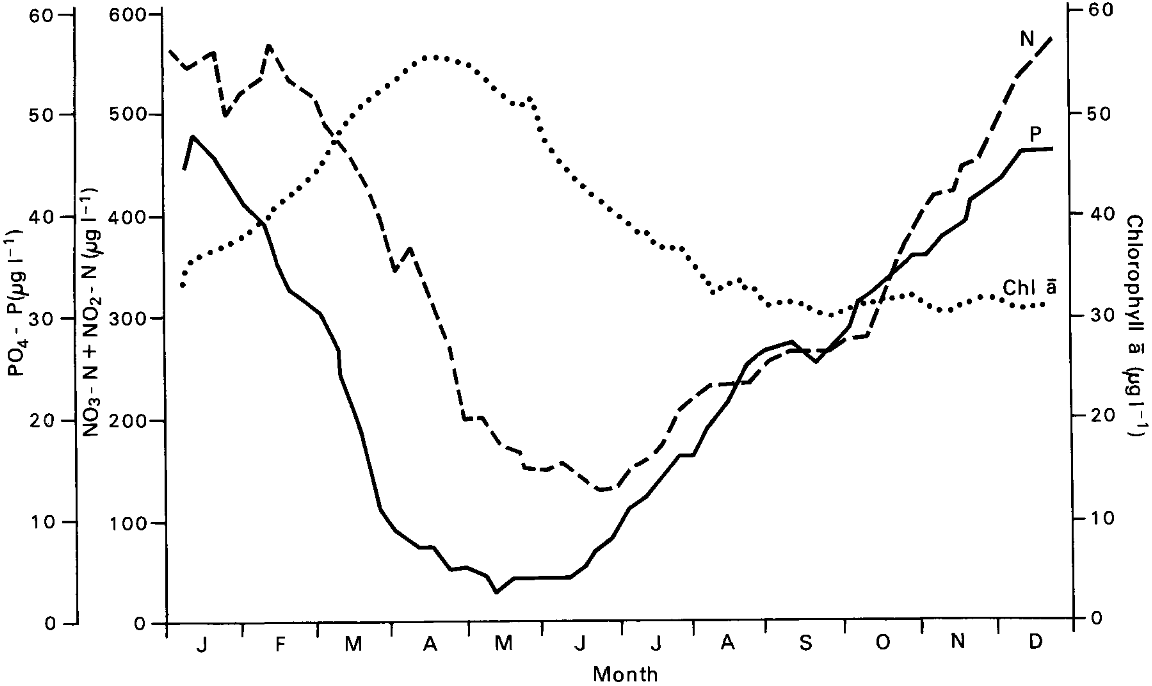
4.87. It is generally accepted that the main causes of excessive algal growth are an overabundance of nitrogen and phosphorus although other elements are involved. For any particular body of water, the likely algal growth for a given nutrient level can be assessed by tests but it is not yet possible to predict reliably the relative proportions of different species of algae and thus to predict whether growths will occur of species that may create particular problems for water supply. The factors that lead to growths are complex and are not fully understood. It has been noted, for example, that in some waters algal "blooms" are known to have occurred over many decades but that their severity does not appear to have increased in spite of substantial increases in nutrient levels([73]).

4.88. Algae require about 10 to 20 times as much nitrogen as phosphorus. In most UK waters that have been investigated, the amounts of nitrogen available compared with those of phosphorus exceed this ratio, so that phosphorus, more often than nitrate, is likely to be the factor that limits algal growth. This point is illustrated in Figure 4.8 which is based on data obtained from a weekly sampling of algal population and nitrogen and phosphorus concentrations in Lough Neagh over a period of 10 years. It will be seen that the peak of the algal crop coincides with the trough of phosphorus (here expressed as phosphate), suggesting that this element is the limiting nutrient. This appears also to be true for the Norfolk Broads, where there are indications that increased eutrophication over the past decade has been associated with increases in phosphorus levels in the water. We were told by the Anglian Water Authority (AWA) that the increases were undoubtedly due in large measure to steady increases in the amount of sewage effluent entering the Broads; the area had one of the fastest growing populations in the country and in addition, the mains sewerage system was steadily being extended to rural communities. Only Hickling Broad did not receive sewage effluent but here the phosphorus came from the droppings of gulls, which in recent years had increased to vast numbers and which used the Broad as a resting place.The reason for this increase is unknown. We note with interest that the AWA is conducting an experiment at its Stalham sewage treatment works, to reduce the levels of phosphorus in domestic effluents that reaches the nearby Barton Broad.

4.89. However, it is possible for accelerated eutrophication to arise in the absence of sewage effluent. This has happened in some water supply reservoirs which are fed by streams draining primarily agricultural areas. Agricultural practices can also contribute appreciable amounts of phosphorus, for example through excessive applications of animal wastes or through soil erosion. Thus, while the control of eutrophication through the reduction of nutrient input would generally call for treatment of effluent from sewage works, it also has implications for agriculture and points to the importance of using fertilizers (including manure and slurries) efficiently and to the desirability of adopting farming techniques to reduce the nutrient losses due to erosion. Although there is a good deal of information about eutrophication in particular waters where the process has reached the stage of causing problems, there is at present no nation-wide picture of the degree of eutrophication in surface waters or of the rate at which it is changing. We agree with a view put to us by DOE that the stage has been reached where the need for more systematic monitoring of eutrophication trends in still waters should be considered and we so recommend.

Figure 4.8

Ten Year Averages of Annual Cycles of Nitrate + Nitrite, Phosphate and Chlorophyll ā in Lough Neagh



SOURCE: Professor R.B. Wood, New University of Ulster (1978)

Fertilizers and the ozone layer

4.90. Ozone is formed in small quantities in the stratosphere (that region of the atmosphere extending from a height of about 10 km to about 50 km) by the action of solar radiation on oxygen. It acts as a filter to solar radiation and is one of the factors controlling the heat balance of this planet. The amount of ozone in the stratosphere is determined by the balance between processes of production and destruction; while globally the amount remains roughly constant, from day to day there may be quite large fluctuations in the amount of ozone above a given spot on the earth's surface. The destruction of ozone is catalysed, in a complex cycle of interwoven chemical reactions, by water vapour and by oxides of chlorine and nitrogen. These oxides are naturally present in the stratosphere but concern has arisen over the possibility that human activities might increase their quantity to the point at which the balance is tipped in the favour of destruction. A decline in the amount of stratospheric ozone might cause changes in the world's climate and would lead to a rise in the intensity of ultraviolet light reaching the ground with consequent risk to living things. It is known that there is a correlation between exposure to certain frequencies of ultraviolet light and the incidence of certain forms of human skin cancer. The incidence of such cancers has risen over the last 30 years as changing social habits and styles of dress have led to increased exposure to the sun. Much attention has therefore been given in recent years to the clarification of two issues, namely, the extent to which human activities might change the amounts of oxides of chlorine and nitrogen in the stratosphere and the extent to which such changes might alter the density of the so-called ozone layer.

4.91. The quantity of chlorine oxides in the stratosphere is increased by the release of chlorofluorocarbons used as refrigerants and as propellants in aerosol containers and there has been much concern about the effects of such releases on the ozone layer. This is a matter on which we continue to keep ourselves informed but it is not relevant to our present study, since agricultural activity does not release significant quantities of chlorine compounds. However, nitrogen oxides are present in the stratosphere almost wholly as a result of biological denitrification at the earth's surface. The question to be answered, within the context of this report, is to what extent the cultivation of the soil and, in particular, the use of artificial fertilizers increases the quantity of nitrogen oxides in the stratosphere. Biological denitrification gives rise to two gaseous products, nitrogen and nitrous oxide. Nitrous oxide can, under the influence of solar radiation, give rise to products that catalyse ozone destruction. However, there is now some evidence that in doing so it can suppress other destructive reactions and therefore enhance the stability of the ozone layer([74]). Moreover, the proportions of nitrogen and nitrous oxide released during denitrification may depend on the way in which the soil is cultivated([75]). It is evident that there is still much to be learned.

4.92. This uncertainty has been acknowledged by a Royal Society Study Group on Pollution in the Atmosphere([76]) who have recommended further study of the relationships between atmospheric concentrations of nitrous oxide and biological activity in soils and waters. A similar conclusion was reached by the Panel on Nitrates of the US National Academy of Sciences in their detailed report *Nitrates: An Environmental Assessment (Scientific and Technical Assessments of Environmental Pollutants)*, published in 1978. The panel pointed out that there were many unknowns in the possible link between nitrogen fertilizer use and ozone depletion, including the fraction of nitrogen and nitrous oxide formed in the oceans and the soil; the sensitivity of stratospheric ozone to increases in nitrous oxide; and the length of time nitrous oxide remains in the atmosphere. The Panel recommended that research on these matters should continue. We have received no evidence that would lead us to dissent from the view also expressed by the Panel that, in view of the uncertainties underlying the calculations, of the length of time for any significant effect to occur, and of the agricultural benefits of nitrogen fertilizers, "no immediate corrective action" is required.

CHAPTER V

FARM WASTES

Introduction

5.1. In previous chapters we have considered the pollution risks arising from the use of pesticides and of nitrogenous fertilizers. The third main area of agricultural activity that may cause pollution is the disposal of farm wastes. Such wastes arise in various forms; we take the term to cover, for example, manures and slurries from farm livestock, cereal straw (which may be disposed of by burning), silage effluent, sheep dip liquors and empty (or part-empty) pesticide containers. In this chapter we examine the pollution problems that are posed by these forms of farm wastes. As we noted in paragraph 1.9, we were particularly assisted in this part of our study by the ACAH report on pollution from the disposal of farm waste([3]).

5.2. While "waste" is a convenient general term to apply to materials that need to be disposed of, it must particularly be questioned whether the term is appropriate to describe animal excreta, which have considerable nutrient value. The Commission touched on the question of the disposal of slurry from intensive livestock husbandry in earlier reports. In its First Report (1971)([42]) the Commission commented:

> "If this material is not rcturned 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 units."

In its Fourth Report (1974)([45]), the Commission observed that increases in the price of chemical fertilizers had given an added inducement to farmers to return manures to the land and urged that a continuing effort be made to improve storage facilities for excreta on the farm so that the material could be applied to the land at the optimum times in order to supply crop needs whilst minimising pollution risks. These are points that we have been concerned to investigate further in our present study.

Animal manures and slurries

Trends in livestock husbandry

5.3. In Chapter II we described the changes in livestock farming that have taken place in this country in the last two decades, in particular the trend towards intensive livestock husbandry. Figure 2.5 and Tables 2.3 and 2.4 indicate (for England and Wales) how herd and flock sizes have increased and the extent to which large-scale enterprises are being established on relatively small areas of land. Much modern intensive animal production is virtually a factory process for converting grass or grain into meat or eggs.

5.4. Over recent years there has been a gradual polarisation of agricultural production as livestock units have been sited either close to their market or to their feed sources. This has meant that dairy, beef and sheep production has tended to concentrate in the wetter western half of the country where grass grows well, whereas intensive pig and poultry production has tended to concentrate in the eastern side of the country where the cereal feedstuffs are grown. The largest concentrations of pig production units are found in Norfolk, Suffolk and Humberside. The majority of the large poultry broiler units are found in the eastern and south-eastern regions, although the large holdings of laying hens are fairly evenly spread throughout the country (see Plate 5.1).

5.5. The change in the techniques of livestock husbandry requires new approaches to the disposal of animal excreta. In traditional, mixed farming systems the manure produced is part of a balanced, self-sustaining cycle, in which nutrients are returned to the land. There is generally sufficient land for disposal and any surpluses are usually readily taken by neighbours. The manure, produced by straw-bedded systems, is accumulated in dung heaps.

Plate 5.1. An intensive livestock unit: one of a number of broiler houses in a large modern enterprise.

Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

During the winter months the dung undergoes aerobic fermentation, that is fermentation in the presence of oxygen which permeates the dung heap because the straw in it maintains an open structure. During this process, pathogenic organisms are likely to be destroyed by the high temperatures generated within the material. The aroma of the resultant manure, both when it is stored and when it is spread on the land, is commonly accepted as being a "good country smell". In the spring the farmyard manure is returned to the land as a fertilizer and as a good conditioner of the soil. Given good management, the storage and spreading of the manure presents no significant pollution problems.

5.6. In contrast, intensive livestock units may be operated as isolated enterprises, having no necessary relationship with other farming activities; they are not conditioned by the weather, type of soil and other variables that make farming an art as well as a science and which have been adduced to justify the special treatment accorded to agriculture in our legislation. Feedstuff may be bought-in and the area of land available for the disposal of excreta may be far less than that required for the nutrient value of this material to be efficiently used (Table 2.6). In these circumstances the excreta may indeed be regarded as a waste; that is, as something of little intrinsic value, to be disposed of as cheaply as possible. The quantity of excreta produced poses pollution risks substantially greater than those arising from traditional agriculture. For these reasons we consider that intensive livestock units are not intrinsically agricultural in character; they are essentially industrial enterprises and should be regarded as such. Much follows from this, as we discuss later in this chapter and in Chapter VII. In particular, as with other industries, the need for pollution control, and the need to bear the costs of that control, must be accepted.

5.7. The environmental problems that may be caused by the disposal of excreta from intensive livestock units are exacerbated by the trend away from farmyard manure to slurry systems. Various factors have contributed to this trend, including the declining labour force and the need to adopt systems which are more amenable to mechanisation. In many slurry systems the mixture of faeces and urine produced by the animals is allowed to fall through the slatted floors into channels or pits whence it can be washed or scraped into storage tanks or lagoons (see Plate 5.2). If the slurry then remains undisturbed it undergoes anaerobic fermentation, that is fermentation in the absence of oxygen, and chemical compounds such as ammonia, hydrogen sulphide, mercaptans and skatoles are formed. These products are odorous, the mercaptans and skatoles being particularly offensive. Whenever the material is disturbed, either during storage or during spreading operations, the odorous products are released. Once the material is spread on land it gradually oxidises and the smell disappears. The anaerobic process engenders less heat than does the aerobic process, so that there is a greater risk that pathogens may not be destroyed. Moreover, compared with farmyard manure, slurry poses a greater risk of water pollution, as we discuss further below.

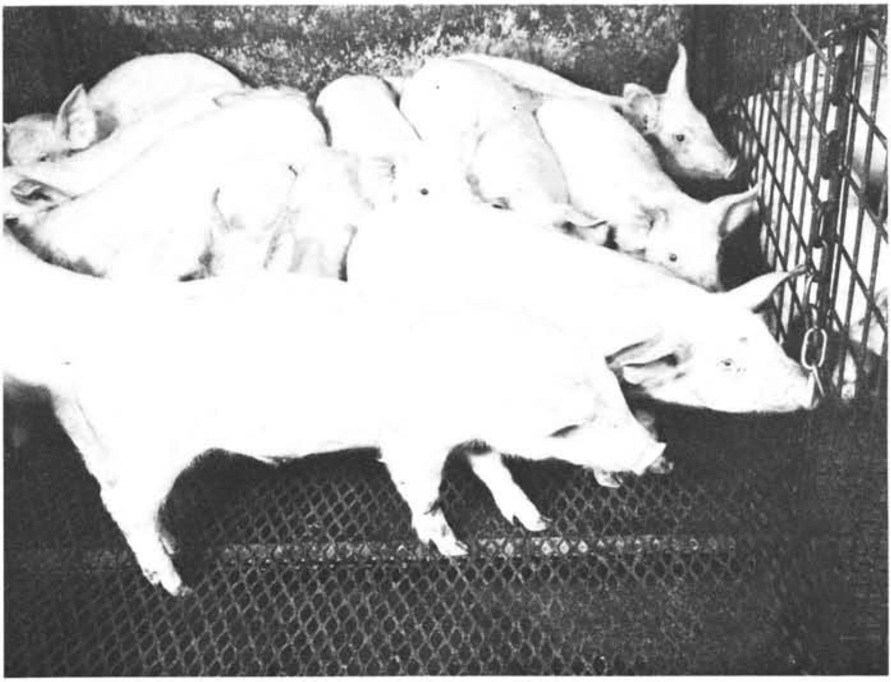


Plate 5.2. A modern weaner unit showing an open grid floor through which faeces and urine fall into a channel beneath.

Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

5.8. The extent to which slurry systems have been adopted is indicated in the following brief survey of data on livestock production. Dealing first with England and Wales, it was estimated in 1976 that 32 per cent of dairy farms used slurry-based systems and a further 20 per cent were partly slurry-based (see Plate 5.3). Forty-five per cent still used straw bedding to produce farmyard manure in the traditional way, and the remaining 3 per cent of the herds wintered outside, thus presenting no problem of manure disposal.

5.9. Most poultry are now kept in very intensive systems. In 1976 there were 60 million laying hens and pullets, of which some 50 per cent were housed in 375 units. There were also 50 million broilers, of which 90 per cent were housed in about 500 units. The litter, that is the mixture of bedding, excreta and dropped foodstuff from broilers and the other meat poultry, is usually handled in solid form. Recent developments in laying-hen house systems now allow much of the battery cage droppings to be collected in dry form, whereas in some of the earlier systems it was handled as slurry (see Plate 5.4).

5.10. The pig population in 1977 was 6·7 million. The average number of pigs per unit was about 210 head. There were 1,000 units with between 1,000

Plate 5.3 Slurry being scraped from modern cow housing.
Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

and 5,000 pigs, and there were also units of 10,000 pigs or more, although these were rare. It was also estimated at that time that about one quarter of the pigs were on holdings with insufficient arable land to make profitable use of the manure produced, although most of the excess was used profitably on other farms.The manure from the pigs is largely handled in the form of slurry.

5.11. Beef cattle are generally farmed in the traditional manner with the stock out of doors for most of the year. Where there are intensive units, they are usually situated on large arable farms so that the disposal of the manure presents little problem, if any. So far, large beef-lots on the American pattern have hardly appeared in this country. Veal calf production is restricted to a few intensive units. There are some 19 million sheep, most of which are out of doors for the entire year; their excreta are dropped as they graze and pollution problems do not arise.

5.12. In Scotland, only a negligible amount of poultry waste is handled in the form of slurry. In the pig industry 58 per cent of the manure takes the form of slurry. For 42 per cent of this material, storage capacity for 4 to 5 weeks is available, and longer term storage is available for the rest. DAFS has not yet surveyed cattle manure disposal systems, but the department considers

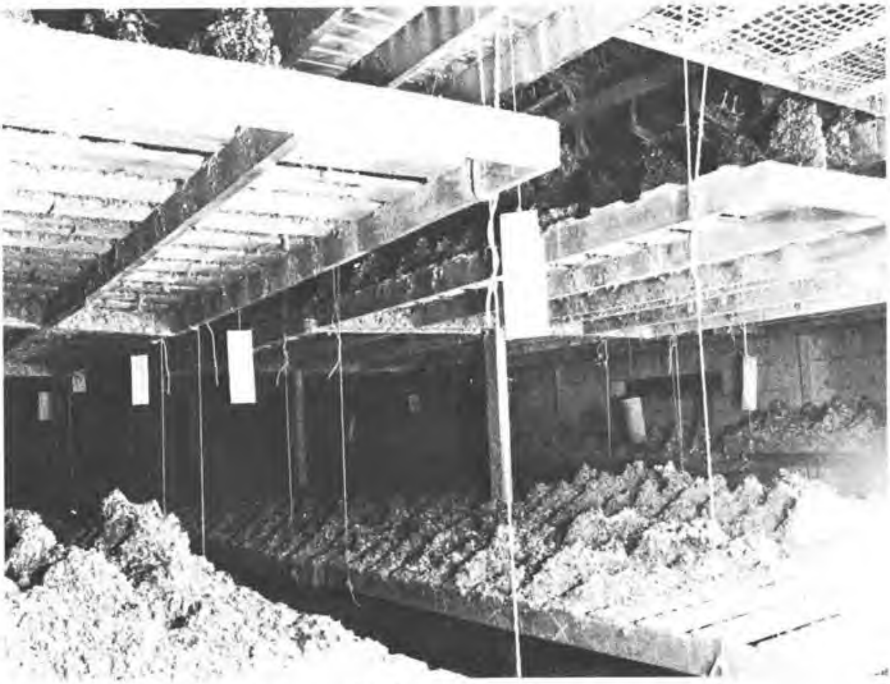


Plate 5.4. The pit beneath a battery hen house where droppings accumulate.

Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

that during the past 10 years there has been a substantial swing from traditional byre accommodation for dairy cows to the cubicle/slurry system. There are about 11 million sheep in Scotland.

Amounts of excreta produced

5.13. It has been estimated that some 170 million tonnes of undiluted excreta are produced by farm animals in the UK each year. About 60 million tonnes are voided indoors whilst the rest is returned directly to the land by grazing animals. The amounts of excreta produced by different kinds of livestock are shown in Table 5.1; it will be noted that a high proportion of the material consists of water.

5.14. Various comparisons have been made between the pollution load represented by animal and human excreta, assessed in terms of its Biochemical Oxygen Demand (BOD)*. It has been estimated that, in the UK, the pollution load of excreta produced by farm animals is equivalent to that of 150 million people, that is over two and a half times the present population of these

*BOD (Biological or Biochemical Oxygen Demand) is a measure of how readily an effluent, during the natural processes of oxidation to which it is subject, removes the oxygen dissolved in the water of a river or stream.

islands. In the United States, it has been estimated that farm animals produce ten times as much waste as does the human population of that country. Put in another way, a modern family farm of 40 hectares, carrying a dairy herd of 50 cows and a pig population based on 50 sows, has a potential pollution load equivalent to that of a village of 1,000 inhabitants. The need to provide sewage plants to treat human waste is commonly accepted; it seems paradoxical that most animal excreta in slurry form are applied to land without prior treatment.

The nutrient value of animal excreta

5.15. Although excreta are an excellent source of plant nutrients (Table 5.2), the amounts of nitrogen, phosphorus and potassium they contain are not balanced for crop growth. In particular, the quantities of potash and phosphorus are high relative to the nitrogen content; to apply the required amount of nitrogen could result in more potash being applied than plants require. Applications of mineral fertilizers are likely still to be required to achieve a proper balance.

TABLE 5.1

Approximate Amounts of Excreta Produced by Livestock

Type of Livestock	Amount of Excreta (faeces & urine) litres/day	Moisture content of excreta %
1 dairy cow	40	90
1 pig. Dry meal fed	4·5	90
1 pig. Liquid fed	7	91
1 pig. Whey fed	13	96
1,000 laying hens	114	75

TABLE 5.2

Available Nutrients in Undiluted Slurry

Type	N Kg/100 litres	P_2O_5 Kg/100 litres	K_2O Kg/100 litres
Cattle	2·5	1·0	4·5
Pig. Dry meal fed	4·0	2·0	2·7
Poultry	9·0	5·5	5·5

5.16. MAFF has estimated that for the year 1976, livestock manures in England and Wales contained 182,000 tonnes of nitrogen, 84,000 tonnes of phosphorus and 240,000 tonnes of potassium as potentially available plant nutrients. These figures represent 21 per cent, 27 per cent and 75 per cent respectively of the total usage by farmers of nitrogen, phosphate and potash in organic form in 1975/76. The figures exclude the excreta dropped on pastures by grazing animals. On the other hand, they do not allow for losses during storage or spreading. For example, nitrogen is lost from farmyard manure and slurry by volatilisation as ammonia during storage and further losses occur after spreading unless the material is immediately ploughed into the soil. Losses of nitrogen from open lagoons can be as high as 60 per cent. As with inorganic fertilizers, nutrient losses may occur as a result of leaching and surface run-off, especially if manure or slurry is applied to land in excessive amounts or at the wrong time.

Pollution risks from animal excreta

5.17. The storage and disposal of large amounts of animal excreta that are produced in intensive livestock units can cause pollution in several ways. The pollution problems that arise are localised and usually sporadic and appear mainly to be due to pig and poultry units rather than to cattle units. We are concerned particularly with the pollution risks attaching to slurry based systems.

5.18. *Water pollution.* Slurry can pollute water courses either by direct discharge from over-filled or defective lagoons and tanks, or by surface run-off or drainage after application to the land, especially where excessive amounts are applied. The risk of pollution through surface run-off is increased if the slurry is applied to sloping, waterlogged or frozen land. Because of its high BOD (see paragraph 5.14), slurry may so deplete the oxygen content of the water that fish and other aquatic life may die. Disease organisms in the slurry, such as *Salmonella* (see paragraph 5.20), can also be spread through polluting the water. The nitrogen and phosphorus contained in the slurry will add to the problems of high nitrate levels in drinking water, and the eutrophication of surface waters, which we discussed in Chapter IV. The application of excessive amounts of manures or slurries to land can also be damaging to agriculture; nitrogen and potassium in the soil can reach levels that would adversely affect crop production and livestock respectively.

5.19. Such pollution risks can be avoided or minimised by care in the siting and construction of waste storage facilities and by conscientious management and control of these facilities and of subsequent spreading operations. We saw on one of our visits an example of pollution due to poor siting and construction; a badly-constructed lagoon placed on steeply sloping land had burst its banks, causing gross pollution of the ditch below.

5.20. *Transmission of disease from animal excreta.* A wide range of disease-producing organisms may be carried by animals without the animals necessarily showing evidence of disease. Excreta from these animals may harbour such organisms, which can survive long periods of storage. From the point of view of both animal and human health the greatest hazard is posed by *Salmonella*. In one survey ([77]) of 187 samples of cattle slurry, 20 yielded *Salmonella;* in another ([78]) the slurry from 12 of 54 pig farms was found to be infected with *Salmonella*. Similarly, a recent MAFF survey showed that 27 of 64 samples of poultry manure yielded *Salmonella* on culture. Some infections are spread by normal grazing and by the application to land of manure in solid form but the risks are greater from slurry because it is spread more widely over pasture.

The risks to health are similar to those that arise from the disposal of sewage sludge on land and we discuss this aspect in more detail in Chapter VI.

5.21. In order to minimise the risk of infection farmers are officially advised to apply slurry to arable land or to grassland intended for hay or silage. If that is not practicable, then the slurry should be stored for at least one month before being spread onto grazing land and the land should then be left ungrazed for at least 6 weeks. Farmers are also advised not to apply slurry with a spray gun, especially in livestock areas, since the spray can drift for considerable distances and might infect cattle directly or contaminate land. Specific orders made under the Diseases of Animals Act 1950 prohibit the disposal of manure or slurry in particular circumstances, for example, in foot-and-mouth disease infected areas. Similar prohibitions may apply under various MAFF Tuberculosis and Brucellosis eradication schemes.

5.22. Contamination of land, and harm to crops or livestock, may also be caused by elements other than nutrients that may be present in animal excreta, especially by substances that are used as additives in animal feedstuffs. For example, copper salts are used as additives in the diet of fattening pigs and concern has been expressed that crops grown on land on which excessive amounts of pig slurry have been spread may be contaminated with undesirably high levels of the element, sufficient to harm livestock which feed on them. We were informed that, in practice this does not appear to be a problem.

5.23. *The smell problem.* It is clear that the smells associated with intensive animal production give the most offence to, and cause most complaint by, the public at large. It is also the most difficult problem to define. The reaction to smells and the assessment of their intensity are highly subjective matters. However, refined measurement is unnecessary to establish that the smell created by intensive livestock units can be very objectionable. We are talking here of smells that are far removed from the "good country smell" of farmyard manure. The smell of pig slurry, as we experienced when visiting Humberside with its many pig units, is highly offensive and penetrating. Those people unfortunate enough to be living or working downwind when pig slurry is being spread on the land may well find the smell intolerable. In broiler and veal calf units the smell problem is intensified for a week or two at the end of the creatures' brief life-cycle, when the accumulated excreta and dropped feedstuff in the bedding encourage extensive fungal and bacterial growth and an extremely strong ammoniacal smell is produced. This smell builds up and is then vented outside of the building,

5.24. The problems of smell nuisance are mainly associated with intensive animal production and are more acute when intensive units are close to settlements or when the units need to export excreta for disposal on other farms that are so sited. Much can be done to minimise the smell nuisance by adhering to good management practice both in the rearing process and when the excreta are stored or spread on the land. If slurry can be spread on the

Plate 5.5. Unseparated slurry being discharged close to the ground.

Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

land within one or two days of its production, that is, before anaerobic decomposition starts, much of the smell problem is avoided. The risk of smell nuisance is also affected by the technique used for slurry application, being reduced by the use of slurry tankers having a low trajectory discharge or fitted with low-level dribble bars (see Plates 5.5 & 5.6), or by direct injection into the soil. For a number of reasons, however, such as the avoidance of water pollution, the weather conditions, the farmer's cropping programme or the soil type, it is not usually possible to spread slurry so soon after its production, or at regular intervals. Thus the slurry has to be stored, perhaps for the duration of the winter, and it may then be necessary to consider some form of treatment to facilitate storage and to avoid the risk of pollution and smell.

Control of pollution from intensive livestock units

5.25. There are several aspects to the question of the control of pollution, including smell nuisance, from intensive livestock units. As noted above, the pollution risks are affected by the siting and construction of the units and by the availability of suitable land for disposal of the excreta.These are matters that fall within the province of planning and which should properly be considered in dealing with proposals for extensive livestock unit development, or for urban development close to existing units. Again, the risks of pollution

Plate 5.6. A dribble bar boom for applying the liquid fraction of separated slurry.

Photograph by courtesy of National Institute for Research in Dairying.

are affected by operational practices. Clearly, good management will do much to minimise the problems but we do not think that this, of itself, provides sufficient safeguards; we have in mind that the trend towards the intensification of livestock holdings is expected to continue, that individual units will become larger and that consequently even greater amounts of slurry will be produced, and will need to be disposed of, in particular localities.

5.26. A related question is the adequacy of the powers available to pollution control authorities to deal with pollution problems arising from intensive livestock units. With regard to smell nuisance, local authorities have powers under the public health legislation to take action in the Courts to secure the abatement of a nuisance. However we were told by the local authorities that there are practical difficulties in dealing with odour nuisance since the nuisance is often a transient one which may well have disappeared by the time the Environmental Health Officer is able to visit the site. It was suggested that a further contraint is placed upon these officers in that they need, ideally, to find solutions that will not impair the relationship between farmers and their neighbours in what are often small, rural communities. The majority of complaints are usually settled by persuasion and discussion, but this is said to be increasingly difficult to achieve since present-day country dwellers are becoming less tolerant of the smells from intensive animal production and from the slurry so produced.

5.27. We reserve further discussion of these matters until Chapter VII where we consider the controls that apply to the development and operation of intensive livestock units and make recommendations for changes in the present arrangements. In this chapter we consider another aspect of control; that is the technical means that are available to reduce smell nuisance problems and the factors that affect the development and use of these means.

Slurry treatment systems

5.28. Forms of treatment similar to those used for domestic sewage can be applied to animal excreta; indeed some farms dispose of their slurry to public sewerage systems. This practice was considered by the Working Party on Sewage Disposal which sat in 1969 under the chairmanship of Mrs. Lena Jeger, MP. At that time it was estimated that at least 4,000 farms were connected to public systems. In its Report ([79]) the Working Party came to the conclusion that this method of disposal would be quite impracticable and uneconomic for adoption on a national scale; the capital investment required at sewage works for the treatment of animal wastes would be much greater per head of stock than per head of human population. The Report therefore recommended that animal wastes should be returned to the land wherever possible. The number of farms at present using the public sewerage system is not known, but it is thought that because of the high cost of that service to the farmer the numbers may well have diminished since 1970. Without question the amount of animal excreta now produced exceeds that of 1970.

5.29. We agree with the views expressed on this matter by the Jeger Working Party. The discharge of slurry to the sewerage system amounts to regarding the material as a waste rather than as a potentially valuable source of nutrients; in any case, it would appear not to solve the disposal problem but merely to transfer it and perhaps make it more difficult. The considerable fertilizer value of slurry suggests that as far as possible the material should be directly used on the land. The need to store slurry at times when it cannot be spread then creates the need for treatment systems which can be used on the farm in those situations where the storage or subsequent spreading of the slurry would otherwise cause smell nuisance.

5.30. There are at present five main categories of treatment available. All of these systems will effectively reduce the smell of the slurry.

(i) *Mechanical separation systems* separate the solid and liquid fractions of the slurry. The solid element is stackable and relatively odour-free. An advantage of this system is that the liquid fraction, which in the fresh state is also relatively free from odour, can be pumped direct to land by means of irrigation pipes.

(ii) *Anaerobic digestion systems* have been developed experimentally, prominently, in the UK, by the ARC Rowett Research Institute which is grant aided by DAFS. There are digester units in use in Europe and elsewhere abroad, although we were informed by MAFF that their utility and economic viability have yet to be proved in the UK under practical farming conditions. This method of treatment greatly reduces the smell of the slurry and as a by-product produces methane gas. The equipment is expensive to install and run and the methane, being explosive, is a hazard. The ways of using the gas as a source of energy on the farm, that is over and above its use in the digestion process itself, requires some thought and further capital outlay.

(iii) *Aeration (aerobic) treatment* may be the most direct solution to the odour problem since the aim is to maintain a positive oxygen balance in the slurry, thus preventing the formation of unpleasant odorous compounds produced during incomplete anaerobic fermentation. Current research is directed to establishing how little oxygen needs to be added to the slurry to reduce its smell to an acceptable level.

(iv) *Composting.* Work in progress shows that composting a mixture of pig slurry and straw in specially constructed chambers can produce a relatively non-odorous material.

(v) *Chemical treatment* may be used to break down or mask the compounds in slurry that produce foul smells. For example, we understand that some intensive production units now have equipment which automatically releases a chemical masking agent when the wind is in an unfavourable direction. It appears, however, that these methods have so far had only limited success.

5.31. Research on these methods of treating slurry to reduce smells has been proceeding for many years. However, we were struck by the fact that in spite of the considerable efforts that have been expended, these techniques appear to have been adopted to only a negligible extent on farms in this country. The NFU expressed the view in its evidence that only a minute proportion of livestock effluent is, in fact, treated or processed in any manner. The Union thought that the principal reason for this is that many systems have been put on the market without proper development in the working farm environment and have proved to be either inefficient or impracticable, as well as costly. Moreover, the increasing cost of inorganic fertilizer, and hence the increasing attractiveness of slurry as a fertilizer, has made it easier for farmers to find neighbours willing to take slurry, thus reducing the need for storage and treatment. The lack of adoption of treatment techniques does not appear to be due to any failure by the farming industry to recognise the importance of smell problems. The NFU acknowledged that these problems, which are almost wholly associated with livestock units, pose one of the most difficult areas of control and are one of the main sources of friction between the farming industry and the community.

5.32. While good design and management of intensive livestock units will often be sufficient to ensure that smell is not a problem, we think that there are probably many units where the avoidance of smell nuisance already strictly calls for treatment of the slurry and that the need for such treatment is bound to increase in the future. The slow progress that appears to have been made in developing suitable systems, and in their adoption on farms, is therefore a matter that concerns us. The uptake of treatment systems by farmers will be affected by various considerations. Cost is obviously a major factor; another is the availability of suitable equipment which is able to operate reliably in the conditions of a working farm. There is the question of the adequacy of the advice that is available to farmers to assist them in choosing appropriate systems. Another important, though more general, factor is the opinion within the farming industry that farmers cannot be expected voluntarily to spend money on equipment solely for the control of pollution and with no financial return; this view was explicitly stated to us by the MAFF Farm Waste Unit (see paragraph 5.42). We think that attitudes to pollution control still reflect the practices of the past; there was no question of expenditure to reduce the smells associated with traditional muck-spreading and recognition of the fact that the disposal of excreta from intensive livestock units poses pollution problems of a different order, which require new approaches for their solution, has been slow to gain ground. We discuss these various factors in more detail in the following paragraphs.

Costs of slurry treatment

5.33. We have not examined these costs in detail but we were informed that they can be substantial in relation to the profit margins of an intensive livestock unit business. The question arises of how such costs are to be covered. Generally the costs of pollution control in an industry will be reflected, like all other costs, in the price of its products. This is what the "polluter pays" principle implies. It is argued, however, that compared with other industries, the livestock producer is more likely to operate under price constraints that prevent him passing on his pollution control costs to the consumer. The ACAH noted in its report[3] that agriculture is a "price taker" as opposed to a "price setter".

5.34. It is not within our remit to consider the factors that determine the financial framework within which farmers must operate. We wish, however, to make strongly the point that agriculture generally and, in the present context, the intensive livestock industry in particular, must come to accept the cost of pollution control in the same way as other industry. If mechanisms indeed exist under the Common Agricultural Policy whereby the production costs incurred by farmers are taken into account in determining prices, then the costs of pollution control should be included and should be uniformly applied to avoid distortions of trade.

Grant aid

5.35. Grant aid to assist with farm development is available under the Farm Capital Grants Scheme (FCGS) or the Farm and Horticulture Development Scheme (FHDS). The FHDS is partly financed by the EEC and grants are available only to farmers and growers with an approved development plan designed to increase their earned income to a level comparable with workers in non-agricultural occupations. The FCGS grant for dairy and beef cattle housing is 30 per cent and the FHDS grant is 40 per cent; for pig and sheep housing, grants of 20 per cent and 25–30 per cent are payable respectively under the two schemes. Poultry enterprises do not qualify for grant under either scheme. In administering grants, Ministry officials must take account of whether provision for the disposal of waste is adequate. Permanently installed waste disposal systems can be grant aided at the rates indicated above for cattle and dairy buildings; for pig and sheep buildings, the rates for such systems are 20 per cent under FCGS and 25–30 per cent under FHDS.

5.36. Of particular interest is the extent to which grant aid is available in respect of provision for the reduction of smell problems. For cattle and dairy buildings, grant can be provided under both schemes, at the rates indicated above, for necessary ancillary equipment and we were informed by MAFF that this could include equipment (such as aerators) to reduce smells. However, grant is not available for this purpose under FCGS in respect of pig or sheep housing; it could be available under FHDS to the extent of 10–15 per cent, subject to the other rules of that Scheme, in particular the requirement that the holding must be capable of producing not less than 35 per cent of the feedstuff required for the pigs on that holding.

5.37. The general policies for agricultural development that are reflected in the grant aid schemes are not our concern. We are concerned, however, that appropriate provision should be made for pollution control in such developments and we do not think that this aspect is sufficiently taken into account in these schemes. For example, it appears illogical that, under FCGS, grant aid may apply to treatment equipment to reduce smells from cattle slurry but may not apply to the provision of this equipment for pig enterprises (which generally create greater smell problems). Again, it appears illogical that, under FHDS, grant aid for treatment equipment should be available only to holdings that have sufficient land to be able to produce a considerable proportion of their feedstuff; such holdings are likely to be those where smell problems are less difficult. Another example relates to grant aid for storage facilities for slurry. The provision of adequate storage is important from the pollution viewpoint; similar considerations apply to storage for silage effluent (see paragraph 5.74). In our discussions with agricultural organisations in Northern Ireland it was pointed out to us that the rates applicable to grant aid for storage facilities are considerably less than those applying to land drainage schemes (currently 50 per cent under FCGS); the high rate for the latter no doubt reflects the importance of land drainage to productivity. It was suggested that the higher rate should apply to storage in order to encourage more adequate provision. We would not necessarily subscribe to this view, but bearing in mind that improved drainage might exacerbate pollution risks arising from inadequate storage, we think that the difference in these rates can reasonably be questioned.

5.38. We have concluded that there is a need to review the conditions relating to grant aid with the aim of ensuring that appropriate provision is made for pollution control, especially for waste treatment facilities for the reduction of smell problems. We accordingly recommend that such a review be undertaken by the Agricultural Departments. To the extent that EEC considerations are involved, we recommend that the Government should pursue this matter in Community deliberations.

5.39. We are conscious of the fact that our views on this matter are to some extent in conflict with views expressed by the ACAH in its report on the disposal of farm waste([3]). The ACAH considered the question of whether there was a case for extended grant aid for the control of smells caused by intensive livestock rearing, specifically for intensive pig and poultry installations. The Council noted that waste treatment installations are not generally eligible for grant under FCGS since they constitute plant and machinery. The Council reached the view that the "polluter pays" principle could not justifiably be breached and that there was no case for Government assistance for new intensive livestock unit projects beyond what could be provided under the existing grant aid arrangements. In reaching this conclusion the ACAH observed that it was now essential for farmers to give the fullest attention to potential problems of smell nuisance in planning new developments.

5.40. We fully accept this latter point; we cannot accept, however, that the case for providing extended grant aid in respect of waste treatment facilities should be ruled out on the grounds of breaching the "polluter pays" principle. To be sure, it is desirable that, so far as possible, new projects should be planned so as to ensure that effluent can be disposed of without creating smell nuisance and without requiring costly treatment techniques. Nevertheless, if the development of an enterprise is judged to merit grant aid on general agricultural grounds, if satisfactory operation from the nuisance viewpoint requires the provision of waste treatment facilities, and if, finally, support for such provision is not ruled out on other, general grounds that would apply to equipment for any purpose, then we consider that the grant should apply to those facilities. Given that grant aid is available for a development, it appears to us to be wrong in principle to argue that it should not apply to pollution control by virtue of the "polluter pays" concept. We believe that necessary provision for pollution control should be regarded as an integral part of any development, not as a separate, "added-on" component to which different considerations apply.

5.41. The ACAH also considered the question of grant aid for pollution control in respect of existing pig and poultry units which are sited close to human settlements, whether because they were originally so sited (possibly even with planning permission) or because they have been overtaken by urban development. We would hope that better understanding by planning authorities of the nuisance problems that may be caused by intensive units will lead to a reduction in the number of cases of this kind in the future; we believe that the measures we propose in Chapter VII would help in this. However, the possibility would remain of urban development being allowed too close to an existing livestock unit, thus creating, through no fault of the farmer, a situation in which smell nuisance could not be avoided, or could be avoided only by the installation of costly treatment equipment. This raises issues which were considered by the Commission, in a more general context, in its Fifth Report([80]). In that report the Commission noted that local authorities could take action in the High Court, under Section 100 of the Public Health Act 1936, against nuisance caused by an industrial works. Such action could result in closure of the offending works without payment of any compensation or damages, even though the situation in which nuisance was caused was created by planning decisions. The Commission recommended that in considering a case brought under Section 100 or similar legislation, the courts should be required to take account of the planning history, and that compensation should be payable by the local authority in proportion to its degree of responsibility. The Government has yet to respond to the Commission's Fifth Report. We support this recommendation; it would apply directly to any case where the closure of an intensive livestock unit was enforced on nuisance grounds but, by an extension of the principle, we think that compensation should also be payable in respect of waste treatment facilities if these would enable the enterprise to continue without creating the nuisance. This mechanism, rather than grant aid, should provide the means for redress.

Advice on farm waste facilities

5.42. The MAFF advisory effort on farm waste utilisation and disposal centres on the Ministry's specialist Farm Waste Unit based at Reading. We were informed that the Unit comprises four specialists and one clerk as supporting staff. Its role is to guide MAFF research in the field of farm waste, and to ensure that the results of that research, together with the knowledge gained from practical experience of particular treatment and disposal systems, are made known to the local advisory staff of ADAS who form the front line of the advisory service to the farmer. There is also, in each of MAFF's regions, a Farm Waste Committee which co-ordinates investigation and advisory work and provides support to local advisory staff. These committees have a liaison role with local authorities, water authorities and similar bodies; some committees have direct water authority representation. The expertise of the Farm Waste Unit is called upon to assist in solving particularly difficult waste disposal problems that arise on farms. We were told that the Unit had made 66 farm visits for this purpose in the past year, followed by some 200 reports or letters of advice to farmers.

5.43. The Farm Waste Unit cannot commission research, but it is directly represented on the MAFF Technical Sub-Committee on Farm Waste whose research recommendations go forward to the MAFF Central Research and Development Committee, chaired by the Deputy Director of ADAS. The final decision on research priorities is the responsibility of the MAFF Chief Scientist Group. We comment further on the question of research in later paragraphs.

5.44. Bearing in mind the responsibilities of the Farm Waste Unit as described above, and the increased emphasis on the development and adoption of waste treatment systems that we believe to be required, we consider that the meagre resources currently available in the Unit are inadequate. We were interested to note that this view was shared by the ACAH which proposed that the complement of specialist staff in the Unit (consisting of three staff at the time of the Council's enquiry) should be doubled. We also recommend that the Unit be substantially strengthened. We comment further on the role of the Farm Waste Unit in paragraph 5.52.

5.45. We have noted that in Scotland the advisory service to farmers is provided by the three Scottish Agricultural Colleges. However, the advisory arrangements work in a similar way; a farmer seeking advice on waste disposal would first consult his local advisor who could, if necessary, call on the resources of the specialist departments within his College. There is not a corresponding group to the Farm Waste Unit and we were unable to ascertain the extent to which the time of the Scottish advisers and specialists is devoted to problems of farm waste disposal or to assess the adequacy of the resources that are available for this purpose. We were told that there is sufficient capacity in the Scottish system to deal with the problems that arise; however, in view of the increased emphasis we wish to see placed on waste treatment facilities, we think that the arrangements need to be reviewed and we so recommend.

Research on farm waste treatment

5.46. Smell problems arise in various industries and have created the need for basic research to find methods of control; some of this work is potentially relevant to the treatment of farm wastes. The lead in promoting such research is taken by DOE in particular by its sponsorship of a research programme at the Warren Spring Laboratory (WSL) of the Department of Industry. This is a co-operative programme of research on the control of odours, stimulated by the Report of the Working Party on the Suppression of Odours from offensive and selected other trades([81]) and involving a number of local authorities and trade associations as well as DOE.The principal aim of the research is to develop guidelines for local authorities and industry on the abatement of industrial odours. The programme includes work on the measurement of odours, on the dispersion of concentrations giving rise to complaint, and on a range of techniques for removing odour-causing substances from emissions to the air. It was suggested to us that some 20 per cent of the research could form the basis of work specifically related to the control of agricultural emissions. However, that degree of relevance to agriculture does not appear to have been reflected in MAFF support of the work; the Ministry has contributed only a modest £10,000 towards a programme cost of the order of £1m. We note here that work on the measurement of odours is of basic importance; it has been suggested to us by several bodies that the lack of a definition of acceptable levels of farm odours is a considerable impediment to research aimed at devising methods of abatement that will be acceptable on cost grounds.

5.47. A varied programme of research is in progress that is directed specifically to the control of pollution from farm wastes. ARC research, both "in-house" and that commissioned by other bodies, especially MAFF, covers a range of projects that have a bearing on odour control. Thus, for example, the ARC National Institute of Agricultural Engineering (NIAE) has considered low-cost aeration systems and the National Institute for Research in Dairying is working on injection techniques for separated liquid and slurries. MAFF has built, and is co-operating with the NIAE in running, an experimental piggery at the Ministry's Terrington Experimental Husbandry Farm which incorporates a new system for slurry treatment aimed at producing an inoffensive solid waste for application to the land. A basic feature of this system is the evaporation of surplus water from the slurry, making use for this purpose of waste heat generated by the livestock.

5.48. The resources applied to this research are considerable; for example, MAFF estimated that in 1976 its total expenditure on research and development relevant to pollution amounted to £1·3m of which £0·25m was devoted to work on farm wastes, including smell problems. Other research in this field is funded by the ARC and by DAFS. We note that the Farm Wastes Technical Sub-Committee of the Joint Consultative Organisation (an organisation established jointly by ARC, MAFF and DAFS to advise on research needs) has assigned top priority to odour research. We were informed that a proposal to increase ARC research effort in this area by 50 per cent had been accepted as a first commitment for new funds. (Such an increase, however, would imply an addition of only four staff.)

5.49. Smell problems from intensive livestock husbandry are not, of course, limited to the UK and much research is being directed to them in other countries. Indeed, the ARC pointed out that the problems are regarded as more serious in some Western European countries than in the UK and that these countries are therefore investigating systems designed simply to control smells. Thus we were informed that, compared to the UK, considerably greater efforts have been applied in France and in the Netherlands to the development of aeration treatment methods. Similarly, work on "air washers" which are claimed to reduce substantially the smells from intensive livestock units, as well as from various industrial processes, has been done largely in the Netherlands and in the Federal German Republic. We share the view expressed by the ACAH(3) on the importance of keeping in touch with these developments, on the need to avoid duplication of effort, and on the possible benefits to be derived from collaboration with our EEC partners in this matter.

5.50. As we have noted, the effort being devoted in the UK to finding ways of controlling smell from intensive livestock units is substantial. We are not satisfied, however, that this effort is commensurate with the importance of the problem, or that it is appropriately divided between the various available options. The NFU expressed the view, which we share, that the development of odour abatement techniques suitable for working conditions is one of the primary needs in agricultural research. We would think that the use of aeration techniques might offer the best prospect for reducing odour problems from existing livestock units and we note that this approach was identified in the

Valentin report([81]) as one of those where further research was needed. We are not clear that research in this area has been given appropriate priority; we were informed, for example, that research at the NIAE on mechanical methods of slurry aeration has been in abeyance for some years. More generally, we note the views expressed by the ACAH on research in its report; while recognising the need for strategic research that might be relevant to longer term development in agriculture, the Council recommended that the future research programme "should place substantial emphasis on the development of suitable low cost solutions to practical problems". We recommend that the Agricultural Departments and the ARC should jointly review their programme of research in this area with these points in mind.

The introduction of new techniques in agriculture

5.51. The problems of moving from research and development of new techniques to their exploitation appear particularly difficult in agriculture. We were informed that the production of agricultural machinery and plant differs markedly from that of most industrial plant. For the latter, manufacturers will generally have research and development capability to prove new equipment before marketing it. However, apart from the large manufacturers who produce tractors and combine harvesters, agricultural machinery firms are mainly small. In a report([82]) on the agricultural industry prepared by the Department of Industry it is noted that many new ideas come from farmers and that while many of these ideas are taken up by existing manufacturers, many others are not; the latter often give rise to local production by new, small companies where the full market potential of the product may not be realised or exploited. The National Research Development Corporation (NRDC) assists companies to bring new products to the commercially viable stage but in the decade 1966–76 the NRDC was able to assist only 22 projects for the whole of the agricultural engineering industry at a cost of less than £0·2m in all. The problems of marketing new plant are added to by the traditional and conservative nature of farming and by the fact that most farms are still small in the business sense.

5.52. These general considerations apply to plant for the abatement of smells from intensive livestock units, which is our particular concern. They point to the need for good communications between farmers, manufacturers, the advisory services and those involved in research. In this matter, ADAS and its Farm Waste Unit have a crucial role in keeping in touch with developments and in providing advice to farmers on farm waste problems; we commented on this point in paragraph 5.42. The ACAH noted, however, that some farmers are unaware that advice is available from ADAS; the Council recommend that more publicity should be given to the scope of this advice and stressed the need to consolidate existing published information on farm waste management and for this material to be kept up-to-date for use by ADAS advisers and the industry. We agree with the Council on the importance of this advisory material. We understand that although much information on waste management is already issued, there is little on treatment systems. We recognise that there may be difficulties in preparing such material in the present state of development of these systems but we recommend that the matter should be reviewed by the Agricultural Departments to see whether more can be done. Another aspect of communications, and one that we welcome, is the "Muck" exhibitions at the Royal Agricultural Society of England shows in 1975 and 1977; we have no doubt that these exhibitions play a valuable part in helping to inform farmers about developments in waste management and the prevention of pollution.

5.53. The agricultural advisory services are already involved in the validation of new ideas for waste treatment but we consider that there is a need to go further in encouraging and supporting new developments. An illustration of the point we have in mind is provided by remarks made to us by a small manufacturer of slurry aeration equipment; he urged the need for an arrangement whereby equipment could be subjected to official tests so that farmers could be guided by independent assessments of manufacturers' claims regarding equipment performance. There is a suggestion at present of a "Catch 22" situation in which equipment cannot be proved until it is used and cannot be brought into use until it is proved. Another example of this concerns the use of equipment to control smells arising from the drying of poultry manure. We understand that there is a technique widely and effectively used in Europe and USA whereby malodorous air is purified by being passed through a bed of compost. We were told of a case where a farmer had been served with an injunction to refrain from operating a manure dryer until it could be effectively deodorised. He wished to install a "compost scrubber" but found himself in a situation where he could not operate the plant until he proved the system but, in the absence of any official ADAS advice, could not prove the system until he had operated the plant.

5.54. With regard to the second example mentioned above, MAFF explained that the farmer's proposed treatment method did not appear promising enough to justify expenditure from the Ministry's limited research funds. Nevertheless, we think that if the proposed technique is as widely used in other countries as we were led to believe, then its performance could be validated by experience in those countries. We are concerned that perhaps the balance of effort as between official research and development and the support and promotion of ideas from other sources is not well judged. We recommend that consideration should be given to this matter by the Agricultural Departments in consultation with the other interests involved. In this context we note the recommendation made by the ACAH([3]) that more encouragement should be given to farmers prepared to innovate.

5.55. Reverting to the points made in paragraph 5.53, we recommend that consideration should be given to the introduction of official testing arrangements with the aim of providing independent assessments of plant performance. We commented on this matter in paragraph 3.97 in relation to the testing of equipment for spreading pesticides. We see this also as providing a mechanism by which new developments could be assessed from the environmental viewpoint. In this context, we would stress the importance of consid-

Plate 5.7. A slurry rain gun in action.

Photograph by courtesy of Ministry of Agriculture, Fisheries and Food.

ering environmental aspects from the outset; it did not appear to us, for example, that this had been done in respect of the use of rain guns for spraying slurry on land (see Plate 5.7).

The wise use of manures and slurries on land

5.56. We have commented on the nutrient value of manures and slurries and on the desirability of returning these nutrients to the land in amounts, and at times, appropriate to the needs of the growing crops. The agricultural advisory services provide advice to assist farmers in assessing the amounts of excreta likely to be produced by livestock, the nutrient content of excreta and the nutrient requirements of crops; an example of this advisory material is provided by Table 2.5. The question arises of the extent to which this advice is heeded and to which the nutrient properties of the excreta are wisely used. Presumably, in those units where excreta have to be "exported" to other farms, the farmers concerned will generally ensure that the amounts they take are appropriate to their use of their land. It would seem more likely that excessive amounts will be applied to land belonging to the intensive livestock units, in the interests of cheap disposals.

5.57. We were assured by the Agricultural Departments that, apart from occasional local difficulties, there should be no problem in disposing satisfactorily of excreta from intensive units. MAFF informed us of a survey of 200 farms which owned insufficient land for the disposal of their slurry. This showed that 75 per cent of the slurry was disposed of to neighbouring farms; most of the remainder was used profitably on land belonging to the units and only a very few could be said to be dumping the slurry. We were not, however, wholly convinced by these assurances. There appears to us to be a lack of information on present practices for the disposal of excreta from intensive units. We understand that a detailed study is in progress which requires the examination of disposal practices within individual parishes and we welcome this. An example of an area where information appears to be deficient is the extent of the storage facilities available for slurry. We were provided with some information on this aspect for Scotland (see paragraph 5.12) but we are not aware that similar data are available for the rest of the UK. Yet the ability to store slurry at times when it should not be applied to land is important from the agricultural no less than the pollution viewpoint.

5.58. While the increasing price of inorganic fertilizers will give added incentives to use manures and slurries, the question arises of whether other forms of encouragement would be desirable. One possibility is the introduction of a system which would promote the wider distribution and use of slurry than is likely to be realised under present arrangements; intensive units will generally seek the cheapest disposal option, which is likely to imply disposal on land as near as possible to the units rather than taking the material to more distant areas where its nutrient value might be used to better advantage.

5.59. This approach has been taken in the Netherlands which has a very high regional concentration of intensive livestock production. In the early 1970s, "manure banks" ("Mestbanks") were set up in the three provinces in that country. We met officials of the Gelderland manure bank during our visit to the Netherlands. The "bank" is basically no more than an official with a telephone whose function is to mediate between farms in Gelderland with surpluses of manure and farms with a shortage of it. Attached to the mestbank are regional officials and advisers whose task it is to promote the responsible use of manure in agriculture, horticulture and silviculture, by carrying out or promoting research and by the dissemination of information. The bank does not handle the manure itself, nor is it involved in transport arrangements. It does, however, subsidise the cost of transporting the manure in semi-liquid form, provided that the distance to be transported is greater than 10 km. The subsidy comes partly from a central agriculture fund and partly from the Province of Gelderland. The farmer receiving the manure pays the balance of the transport cost direct to the contractor. The producer of the slurry is paid nothing. While only a relatively small proportion of the total slurry production of the Province is dealt with through the bank, the advantage is that transfers can be made over far greater distances than would otherwise have been possible.

5.60. We learned that a similar scheme has been introduced, on an experimental basis, in four Prefectures in Japan. Subsidies are provided for the shipment of livestock manure to areas where it is needed for application to the land. The central Government meets half the cost and each of the Prefectures contributes 10 per cent.

5.61. MAFF pointed out to us that livestock densities in Gelderland are very much greater than those in, for example, Humberside. (There are about 2 million pigs in Gelderland compared with about 600,000 in the similar sized area of Humberside.) A detailed examination of the location of intensive units in Humberside had shown that there were very few areas where these units were not reasonably close to suitable disposal land and the Ministry considered that even this region did not appear to warrant special arrangements on the lines of the Netherlands manure banks. Plainly, the case for introducing such arrangements is stronger where livestock densities are higher. We think, however, that arrangements of this kind might be worthwhile, even in areas where the case for them appears much less than overwhelming, in order to encourage the better distribution of manures and slurries. Moreover, the trend towards further intensification of livestock husbandry is likely to continue; even though these arrangements may not be needed now they may be required in the future and we think that the question of the circumstances in which their introduction might be desirable deserves more consideration than it has so far received.

5.62. It appears to us that, as a first step, this matter should be susceptible to theoretical analysis on the basis of assumptions concerning the distribution of intensive livestock units in a region, the amounts of excreta produced, the costs of transport in relation to the fertilizer value of the material and other relevant factors. We are not aware that such an analysis has been carried out and, if it has not been, we recommend that it should be. Apart from its potential value in indicating whether the case for introducing manure bank arrangements merits more detailed investigation, such an analysis might disclose factors that would have a bearing on planning for future intensive livestock unit developments.

Other uses for animal wastes

5.63. In addition to its use as a fertilizer, some animal wastes may also be recycled as an animal feedstuff. The use of poultry manure as a feedstuff component is well recognised although there are obstacles to its full development. Poultry manure from intensive hen houses, which is virtually neat faeces, can be dried to provide protein which can be added to animal feedstuffs. Poultry and pig manures are used in some parts of the world for fish food, either directly or through detritivores such as worms. The recycling of poultry manure, however, has been beset with economic and environmental problems. Energy used for drying may increase costs to the point where bought-in protein is cheaper. The elimination of the unpleasant smell produced during the drying process may require the use of an afterburner in the drier exhaust which further increases cost. For this reason, poultry houses designed for natural drying may prove increasingly beneficial if energy costs continue to rise.

Poultry litter from broiler houses can be ensiled by relatively simple means, such as clamping, to provide protein material that can be used in the diet of ruminants. The major problem encountered in this recycling process is the risk of transmitting disease-bearing pathogens to stock and thence to humans. This may occur, for example, when the ensiling process takes place on the farm and inadequate precautions are taken to ensure that pathogens are not carried to the clamp, perhaps on the wheels of vehicles.

5.64. The Commission noted in its Fourth Report that the use of poultry manure as a cattle feed ingredient, though distasteful to some people, represents an environmentally sound re-use of materials given that care is taken to avoid health hazards. We share the view expressed by the ACAH that the practice could make a significant contribution to the disposal problem and should be encouraged. We were informed by MAFF that high fuel costs and problems of smell nuisance had resulted in the closure of many plants in the UK although we do not know the relative importance of these two factors. To the extent that the latter is the principal cause, this would add emphasis to the need to find ways of controlling smell.

Straw burning

5.65. Stubble burning has been practised for many years and is considered to be a good agricultural practice because of its beneficial effects in controlling crop diseases and weeds. Straw burning is a more recent development and is the result of changes in livestock husbandry and in regional patterns of agriculture. The move towards greater cereal production and less livestock production in areas particularly suited to arable farming has led to surpluses of straw in those areas, and from the early 1970s much of this has been disposed of by burning in the field along with the stubble. MAFF estimated that in 1976 over 2 million tonnes of straw were burnt. There appears to be some evidence that the burning of straw with stubble, as compared with the burning of stubble alone, may offer agricultural advantages, especially where direct drilling is employed for the subsequent crop. We were informed by MAFF, however, that straw burning is to be seen as a method of disposal which is adopted because there is no better alternative. The other disposal option that is directly available to farmers is that of ploughing in the straw, preferably after chopping, as is done in some other countries. This method is more expensive, however, and under some conditions, especially in heavy soils, it can result in adverse effects on future crop yields because of reactions within the soil. We refer below to possibilities for disposing of straw off the farm.

5.66. Particularly in the early years during which straw burning became widespread, the practice caused much public concern. The smoke and smuts from burning may cause substantial, if short-term, air pollution in the locality, and may pose a hazard to traffic if the smoke blankets roads. Unless proper precautions are observed, the fire can damage trees, hedges and wildlife and endanger crops and buildings. There was early appreciation of these risks within the farming industry and the NFU first issued a code of practice on straw burning in 1964. The code of practice has been subsequently revised in the light of experience.

5.67. We have not thought it necessary to consider the problems arising from straw burning in detail, partly because they have been fully examined by other bodies (notably by the ACAH in a report published in 1973([83])) and partly because it appears that the problems have decreased with the growing appreciation by farmers of the risks and the wider observance of the code of practice. It is perhaps worth noting, however, that in spite of the attention that has been given to the matter, there appears to be little firm and comprehensive information about the damage caused by the practice. We were informed that no information is collected by the Home Office that specifically relates fire damage to straw burning; and the NCC stated that although the practice continues to cause damage to hedges, trees and woodland, the overall effects have never been assessed. The data for cost benefit anslysis are therefore not available.

5.68. There are various possible other uses for straw. One that shows considerable promise is its use after alkali treatment as an animal feedstuff. There is also scope for increasing the direct use of straw in packaging and paper making although MAFF expressed the view that because of market factors in the paper industry, the production of straw pulp would make no contribution to the utilisation of the surplus before the late 1980s. Another possibility is to burn straw in specially constructed boilers so as to generate energy on the farm. A general factor affecting the viability of most of these approaches is the cost of transporting straw and there is scope for improved baling to increase the density of packaging of the material and hence improve the economics of transport. These techniques are, variously, already in use to some degree or are the subject of investigation and research. The view of the Agricultural Departments, however, is that the alternative uses are unlikely to take up the quantities of straw produced and that burning in the field will be required for the foreseeable future.

5.69. We would wish the development and exploitation of other uses for straw to be encouraged and so avoid the waste of this resource. This should include the ploughing-in of straw which we mentioned above (paragraph 5.66); the ACAH noted in its report([83]) that the technique could be beneficial on some soils and remarked on the need for more information on methods of incorporating straw into the soil and on the scope for improved methods. Although this method is more expensive than burning, it is possible that the cost could be reduced; in any event, we consider that the additional cost should properly be weighed against the problems and risks attendant on burning.

5.70. Nevertheless, we accept the need in present circumstances for much straw to continue to be burnt in the field. The powers available to deal with problems that may arise from straw burning appear to be adequate at present, at least so far as risk to life and property and the causing of nuisance are concerned. In addition to action through the nuisance provisions of the Public Health Act 1936 and Section 140 of the Highways Act 1959, local authorities may make bye-laws under the Local Government Act 1972; many authorities have introduced bye-laws based on a model prepared by the Home Office, which incorporate the enforceable provisions of the NFU code of practice. We were informed by the Association of District Councils that representations had been made for an increase in the penalties for infringement of the model bye-laws.

5.71. Compared with other industries, which are subject to strict controls on smoke and other emissions, agriculture is in a privileged position in the matter of straw burning. The privilege imposes special obligations on farmers, not least in their role as custodians of the environment; a disciplined and conscientious attitude is essential. We have no reason to doubt that farmers behave responsibly but we would stress the importance of meticulous observance of the NFU code of practice.

Silage

5.72. In the United Kingdom the season for active grass growth is limited by climatic factors and although there may be some winter grazing it will be insufficient to meet the full needs of livestock. In order to supplement the winter rations, farms conserve, either as hay or silage, surpluses of grass that occur in the peak growth period in May, June, or in early autumn. Silage is made by storing green forage crops under anaerobic conditions. The fermentation of the crop, sometimes assisted by chemical additives, produces organic acids which preserve the material against further microbial breakdown. The resulting product then has a nutritive value similar to that of the fresh crop.

5.73. There are advantages in making silage: it is less vulnerable to our unpredictable weather conditions than is hay making, and earlier cutting is also possible which allows quicker regrowth of the grass. For these reasons, the amount of silage made has steadily increased; we were informed that the amount of grass silage made in England and Wales increased from about 5½ million tonnes in 1970 to nearly 17 million tonnes in 1975. In 1978, 22 million tonnes were produced in the two countries compared with 6·8 million tonnes of hay. The NFU considered that the upward trend would continue although MAFF commented that through improved techniques becoming available there might be a trend back towards the making of hay rather than silage.

5.74. Silage making generally produces an effluent which can cause serious pollution if it is allowed to enter watercourses. The effluent has a very high BOD ranging from 12,000 to 80,000 mg/l; this may be compared with the general standard for treated sewage effluent which requires a BOD value not greater than 20 mg/l. Even in small amounts, the effluent can cause rapid deoxygenation of the water with the resulting death of fish and other aquatic life. In addition to a very high BOD, the effluent may also be very acidic.

Thus it can damage the silo, or the silo catchment tank, in which it is stored, and it will scorch crops and grassland if it is applied indiscriminately to the soil. No means of treating the effluent to reduce its polluting nature has yet been found and the best means of disposing of it, after dilution by water, is back on to grassland where it has a small fertilizer value. Badly made silage also has a most unpleasant smell but it does not appear that this constitutes a significant problem.

5.75. The amount of effluent produced depends on various factors but particularly on the moisture content of the ensiled crop. Most crops are high in moisture content (75 per cent or above); very little effluent is produced from crops with less than 75 per cent moisture but at 84 per cent some 450 litres of effluent may be produced per tonne of fresh crop, half of this being produced in the first week after ensiling. Official advice available to farmers stresses the highly polluting nature of silage effluent and explains that the problem may be largely overcome if the dry matter content of the silage is kept up to 25 per cent or more. The farmer is therefore advised to wilt the cut crop, that is, to leave it in the field to dry for 24 hours or more before being carted to the silo or clamp; this practice also improves the quality of the silage. However, weather conditions may prevent adequate wilting so that the production of effluent is unavoidable and farmers are therefore advised to make adequate provision for collection of the effluent in a leak proof tank. Silos or clamps should be sited well away from watercourses.

5.76. Regrettably, these simple safeguards have not always been observed.The NFU commented that pollution due to silage effluent is probably the single most frequent cause of prosecutions brought by water authorities against farmers. In Northern Ireland, where pollution incidents due to silage effluent seem to be particularly frequent, there were 200 incidents in 1976. In England and Wales in that year there were 136 incidents resulting in 8 prosecutions. These figures must be seen in context; there were at that time some 11,000 farms producing silage in Northern Ireland and perhaps 30,000 in England and Wales. The number of incidents still appears unacceptably high, however, bearing in mind the ease with which they could have been avoided.

5.77. The siting of silos and the provision of sufficient storage for the effluent are important points from the pollution viewpoint. The NFU informed us that, in the late 1960s, the Union had been concerned that many grant aided developments involving silos made insufficient provision for effluent storage; the question was taken up with MAFF and the Union was satisfied that this aspect is now given adequate consideration. MAFF assured us that over the last three years virtually all grant-aided silage schemes (accounting probably for 90 per cent of the total) have included some provision for effluent collection and storage. We were unable, however, to obtain information on the percentage of farms making silage that now have satisfactory arrangements. The water authorities expressed concern that some silos, including some that had received grant aid, were badly sited; pollution problems had occurred which could have been avoided if the authorities had been consulted at the outset.

5.78. These points raise questions concerning planning and consultation in respect of grant aided developments which we consider in Chapter VII. Subject to the recommendations we make in that chapter, we are satisfied that in view of the extensive advice that is now made available on silage making, and the increased awareness by farmers of the risks, pollution from this cause should be a diminishing problem.

Sheep dipping

5.79. We discuss the pollution risks posed generally by the use of pesticides in Chapter III. Pesticides are used in sheep dips to protect the animals against infestations and the disposal of the resulting liquid can cause pollution of watercourses. As a measure against sheep scab, a compulsory national dipping period has been established as a statutory requirement since 1976. The period has been 8-10 weeks commencing at the beginning of September each year; a 10 week period is planned for 1979. In addition, dipping is undertaken by most farmers at least once a year to control ticks and lice. It has been estimated that up to 63,000 cubic metres, that is about 63,000 tonnes of spent dip may need to be disposed of each year.

5.80. Since 1971, sheep dips have been licensed as veterinary medicinal products under Part II of the Medicines Act 1968; the risks that might arise from disposal are taken into account in giving the licence. One of the licence provisions is that the label of the dips must carry reference to the danger of pollution to watercourses which could be caused if the dip is disposed of carelessly. It is intended that these warnings shall be replaced by an appropriate reference to the MAFF code of practice for the disposal of unwanted pesticides and containers. The code advises the farmer to use a soakaway for the disposal of the spent dip, or, failing that, to spread it on the nearest suitable level area of soil. In either event, care must be taken to prevent the dip from running or seeping into sewers, streams, ditches and the like. The code also advises farmers to consult water authorities on the siting and construction of the dips.

5.81. The only chemical authorised for use against sheep scab is gamma-HCH (lindane), a persistent organochlorine compound. The use of this chemical is considered to be the most effective way of killing sheep scab mites, and the farmer need dip his sheep only once. MAFF informed us that the non-persistent compounds that might be used offered a shorter period of protection against re-infection and necessitated double-dipping. We noted in paragraph 3.22 that there might well be circumstances where the continued use of persistent organochlorine compounds was justified and this appears to be the case with the present use of gamma-HCH in sheep dip.

5.82. Our main concern about sheep dipping relates to the arrangements for informing water authorities about dipping operations. In view of the potential importance to water authorities of dip disposal practices, it would seem reasonable that these authorities should be able to obtain information about the location and times of dipping so that they would be in a position to advise on disposal and thus minimise the risk of pollution. Advance warning of the annual dipping period is indeed given to the NWC by MAFF; at the same time local authorities are informed about the location of the sheep farms. The sheep farmer in his turn is required to give his local authority three days' notice of his intention to dip. The NWC told us initially, however, that water authorities were unable to obtain information from the local authorities regarding the location of individual sheep farmers, or the times that they intended to dip, since that information was regarded as confidential. We were pleased to note that in April 1978, that is, during the course of our study, MAFF agreed that this confidentiality need no longer apply and that the water authorities were at liberty to make their own arrangements with district councils to obtain the information. The NWC have since told us that the arrangements appear to be working satisfactorily.

The disposal of pesticide containers and surplus pesticides

5.83. Because of the extensive use of pesticides in agriculture, the disposal of unwanted chemicals and their containers is an important question; incorrect disposal could pose risks to people, livestock and wildlife and cause pollution of water supplies. We found that little information was available about the numbers and types of containers involved or the disposal methods adopted. Our own enquiries indicated that some 1½ million, 25-litre drums of pesticides are sold to farmers each year, about half of which are made of plastic material and half of metal. In addition, there are large quantities of cans, sacks (both plastic and paper), plastic bottles and cardboard cartons.

5.84. The Deposit of Poisonous Waste Act 1972 and Regulations made under the Act apply to a substantial proportion of pesticides and make it an offence to deposit on land waste of a kind which is "poisonous, noxious or polluting" so as to create an environmental hazard. This Act will be replaced by Regulations to be made under Section 17 of the Control of Pollution Act 1974. Farm wastes are not a controlled waste under the terms of the 1974 Act and are excluded from its provisions, although they could be brought within them by Regulations under the Act. An inter-departmental working party has been considering farm wastes in the light of this Act; we were informed that the working party's preliminary view is that while farm wastes disposed of on the farm might remain outside the scope of the Act, those disposed of off the farm should be brought within its scope. With regard to water pollution, existing legislation will be strengthened when it is largely replaced by implementation of Part II of the Control of Pollution Act; there is, however, already an obligation not to dispose of pesticides so as to cause danger to persons or animals or pollute any water supply. In addition, the Health and Safety at Work etc Act 1974 places on workers and employers a general duty to take reasonable care for the health and safety of those who may be affected by their work activities; this obligation has implications for the method used for the disposal of surplus pesticides and containers.

5.85. DOE expressed some concern to us on the lack of data on the disposal of farm chemicals. The Department noted that while there was no evidence that surplus chemicals and containers were being disposed of irresponsibly, the potential dangers were such that it was desirable to know more about the practices adopted. A survey of all 86 waste disposal authorities in England and Wales had shown that these authorities had been little involved in farm wastes; DOE therefore assumed that the majority of farmers disposed of chemical waste on their own land.

5.86. A code of practice, published by the Agricultural Departments in 1975, gives detailed instructions for the disposal of surplus pesticides and containers. The code stresses the need to plan carefully to reduce the amounts of unwanted pesticides to the minimum. The code provides, for example, that empty metal and glass containers (but not aerosols) should first be rinsed out into spray tanks; the caps or lids should be removed and metal containers should then be flattened and glass containers crushed in sacks. The remains should then be buried immediately at least 450 mm (18 inches) deep in an isolated place away from ponds, watercourses and boreholes. The burial place should be marked and a record kept of the site. Depending on the chemicals they contained, plastic containers should be similarly buried or carefully burnt (see Plate 5.8). It is envisaged that a code on these lines will be recognised statutorily as a code of good agricultural practice when the relevant provisions of the Control of Pollution Act 1974 come into force.

5.87. MAFF had no information on the number of containers disposed of on farms. However, based on the reported experience of its advisory officers, the Ministry considered that containers are generally disposed of in a safe manner and in accordance with the code of practice; the situation was being helped by the change from metal to plastic containers which are easier to crush and burn. MAFF collects information on pesticide disposal in its periodic surveys of pesticide usage; in a survey of 321 farms undertaken in 1975, only 16 of the farmers reported unwanted pesticides and empty containers were disposed of as shown in the following table:—

TABLE 5.3

Method of disposal of containers	*Percentage of holdings using this method*
Burning	66
Burying	43
Council tip, dustbin	21
Dumping	10
Containers still stored on farm	7
Removed by spray contractors	5
Washed out and re-used	4
No containers	2

Plate 5.8. Disposal of pesticide containers in accordance with the approved code of practice. *Photographs by courtesy of Ministry of Agriculture, Fisheries and Food.*

5.88. The water authorities (and in Scotland, the river purification boards) are the bodies whose interests are most likely to be affected by the careless disposal of surplus pesticides and containers. These authorities expressed anxiety about the serious damage that could be caused to water courses, but conceded that no major problem exists at the present time; the number of recorded water pollution incidents caused by improper disposal is relatively small. Some water and local authorities questioned whether the MAFF code of practice is widely enough distributed and others questioned whether farmers are likely to follow in every respect the detailed instructions to be found in the code.

5.89. We are concerned that there should be so little firm information on disposal practices for farm chemical wastes and on the quantities involved. In view of the nature of some of the chemicals involved, the adoption of safe disposal arrangements is essential and we do not think that the small number of actual pollution incidents from this cause provides, of itself, the required assurance that appropriate practices are used. We have no reason to doubt that most farmers dispose of these wastes responsibly but it is a matter of experience that some do not; the point is illustrated by Plate 5.9. In Chapter III we have argued the need for a more professional approach to the use of pesticides; safe disposal of surplus chemicals and containers is an important aspect of this approach.

5.90. We have considered alternative means of disposal, such as a collection and disposal (or re-use) system operated by agrochemical distributors, local authorities or other waste-disposal contractors. Such a system might well be welcomed by some farmers but it would be costly to operate. Moreover, the transport and handling of the containers might well create a greater hazard than disposal on the farm; some containers might still contain toxic material, the labels might have become illegible and the stoppers insecure. Further, we would not wish to impose rigid off-farm disposal conditions on a farmer who already has a suitable site on his farm and who exercises due care in carrying out disposal.

5.91. The question thus arises as to the adequacy of control arrangements relating to disposal practices on the farm. We think that where these wastes are disposed of off the farm they should be treated as controlled waste under Part I of the Control of Pollution Act 1974, in the same way as similar industrial waste. It is in a sense illogical that less stringent requirements should apply to disposal on the farm. However, to regard surplus chemicals and containers as controlled waste in relation to disposal on the farm would imply the licensing of individual farm disposal sites by the waste disposal authorities; this would create substantial administrative complexities which we consider would not be justified. We think that some intermediate provision is needed to cover disposal on the farm. We have not considered in detail how this might best be achieved; our aim, however, is that a competent authority (presumably the waste disposal authority) has the power to ensure that disposal is carried out in accordance with the code of practice and thus to take action to prevent

Plate 5.9. Pesticide containers near a public footpath.

Photograph by courtesy of Environmental Services, Hertfordshire County Council.

pollution incidents occurring. We recommend that this matter be considered further by the Departments concerned. We would expect that in the process, the adequacy of the present system for distribution of the code of practice on disposal would also be reviewed.

The storage of chemicals on the farm

5.92. Farm chemicals may also reach the environment inadvertently through accidents during storage. The nature of the risks was illustrated during the course of our study by a fire that occurred on a farm in Yorkshire (in April 1978) and which resulted in chemicals being washed from a store into drainage ditches and thence into the River Ouse. The Ouse supplies some quarter of a million people with their drinking water but fortunately the water authority was able to close off the intake from the river to prevent contamination of the public supply. Fire involving farm chemicals can create serious hazards for firemen and for farm workers or bystanders.

5.93. It is clearly desirable that farm chemical stores should be carefully sited, constructed and managed to minimise such risks and that due attention should be given to emergency procedures. There are no regulations covering the storage of chemicals on farms, although the general provision of the

Health and Safety at Work etc. Act 1974 apply (see paragraph 5.84). However, much advice is already made available on the siting and construction of stores; the HSE Agricultural Inspectorate provides such advice and guidelines on the storage of pesticides were issued in 1975 by the British Association of Grain, Seed, Feed and Agricultural Merchants Ltd* after consultation with the BAA. The design of chemical stores is covered in the British Standards Institution standard for farm buildings (BS 5502).

5.94. The Yorkshire incident prompted new initiatives on the question of safety requirements for chemical stores. The Yorkshire Water Authority carried out an investigation and the HSE is preparing an advisory leaflet which we understand is to be published shortly. The matter is thus being actively studied and we have not ourselves considered it in detail. We make, however, the following comments. In the first place, we are struck by the fact that on this matter, as on others that fall within our study, several organisations have offered, or are offering, advice. While we applaud the UKASTA initiative in the present instance (and those of other organisations, such as the NFU, in others that we encountered), we believe that it should always be clear where the main responsibility rests for issuing advice. In our view, advice should not only be authoritative but should also encompass matters that transcend sectional interests; it should also not be left to chance. We think that official advice on the storage of farm chemicals should most appropriately be given by the HSE and that such advice should be issued after consultation with other interests involved (including the Agricultural Departments, the NWC, the Farmers' Unions, UKASTA and Fire Authorities).

5.95. There is also the question of whether there is need for tighter control on storage facilities for farm chemicals. It would be a mistake to propose general controls on the strength of an isolated incident; nevertheless, we think that it would be desirable to review current practice on farms in order to assess whether the powers currently available to the HSE Agricultural Inspectorate are adequate to ensure that safe practices are adopted. We recommend that such a review should be undertaken by the HSE, again in consultation with the other interests involved. We recognise that the problem of the risks posed by stores of potentially dangerous chemicals is by no means confined to farms and that it must therefore be examined in a more general context.

5.96. Finally, we think that water authorities should be consulted about the siting of farm chemical stores where the amounts of chemicals involved may be sufficient to create an appreciable potential risk to water supplies. In Chapter VII we consider the need for consultation with water authorities about grant aided farm developments and we recommend (paragraph 7.51) that it should be a condition of grant aid for a development that may cause water pollution that the relevant water authority has been consulted and that its views have been taken into account in the proposals. We would expect this to apply to storage facilities for farm chemicals.

*Now the UK Agricultural Supply Trade Association Ltd (UKASTA) after a merger in 1977 with the Compound Animal Feedingstuffs Manufacturers National Association.

CHAPTER VI

THE EFFECTS OF POLLUTION ON AGRICULTURE

Introduction

6.1. We have so far been concerned with pollution that may arise from agricultural practices. In this chapter we consider the other side of the coin, that is, the ways in which agriculture may be harmed by pollution arising from industrial or urban sources. Such pollution may harm agriculture directly, by adversely affecting animals or crops; it may also carry risks for human health through the contamination of foodstuffs. We begin by considering the use on land of sewage sludge.

The disposal of sewage sludge to agricultural land

6.2. About one and a quarter million tonnes of sewage sludge* are produced annually in the UK by sewage treatment processes and the disposal of this material is an important responsibility of the water authorities†. The figure does not include untreated sewage discharged to sea by sewage outfalls or wastes from septic tanks and cesspools discharged without further treatment but such discharges represent less than 3 per cent of the total amount of sewage produced.

6.3. There are three options for disposal of sludge: to land, to sea and by incineration. Nationally, the proportions disposed of in these three ways are about 68 per cent, 28 per cent and 4 per cent respectively. The pattern of disposal varies appreciably in different regions: the proportion disposed of to sea, for example, varies from about 67 per cent from metropolitan London (amounting to about 5 million tonnes of wet sludge per year) to zero from the region served by the Severn-Trent Water Authority.

6.4. We are here interested in disposal to agricultural land. Sludge may be applied to cultivated land, disposed of in land tips or used in schemes of land reclamation. The percentage disposal to different types of land by the English water authorities and in Wales, Scotland and Northern Ireland is indicated in Table 6.1 which is derived from a survey conducted in 1975. The table shows that for the UK as a whole about 60 per cent of the sludge disposed of to land

*Sewage sludge is the solid material which settles out at any point in the treatment process where sewage is allowed to stand in tanks or ponds. The weights given in this section are of the dry solids content of the sludge which actually consists of about 94 per cent water.

†In England and Wales. In Scotland, the responsibility for sewage treatment and disposal rests with the regional and island councils. In Northern Ireland it rests with the NI Department of the Environment.

is applied to agricultural land. This amounts to a little over 40 per cent of the total sludge production by sewage treatment works.

TABLE 6.1

Percentage of sewage sludge disposed to different types of land in the UK (1975)

		English Water Authorities													
		Thames	North-West	Northumbrian	Severn-Trent	Yorkshire	Anglian	Southern	Wessex	South-West	England	Wales	Scotland	N. Ireland	UK Total
Grazing	U	2	11	6	5	5	1	6	7	42	6	25	1	7	6
	D	26	23	11	11	4	13	3	24	16	15	14	13	22	15
General Arable	U	22	6	25	17	27	43	13	15	<1	20	16	25	0	21
	D	18	9	24	15	12	14	13	4	0	14	22	16	27	14
Horticultural	U	<1	≪1	2	<1	1	2	0	2	0	<1	1	2	0	<1
	D	7	0	0	≪1	<1	<1	≪1	1	0	2	0	0	0	1
Forestry	U	0	0	0	0	0	0	0	0	0	0	<1	0	0	≪1
	D	0	0	0	0	0	0	0	≪1	0	≪1	0	0	0	≪1
Land reclamation	U	<1	4	6	1	5	<1	<1	31	0	3	<1	8	0	3
	D	13	2	2	3	0	0	4	3	0	4	0	0	0	4
Land tip	U	8	30	23	19	42	19	37	7	37	22	19	27	30	22
	D	2	7	<1	27	2	7	22	2	5	12	<1	8	14	11
Allotments	U	<1	<1	≪1	<1	1	0	0	0	0	0	0	<1	0	<1
	D	≪1	7	<1	<1	<1	≪1	≪1	4	0	1	0	<1	0	1

U=Undigested sludge
D=Digested sludge
(sludge which has undergone any heated, cold or aerobic digestion process)

Source: DOE/NWC Standing Technical Committee Report Number 8.

6.5. The table distinguishes between the disposal of undigested and digested sludge. In sewage treatment, the material is first separated into a liquid effluent and raw primary sludge. The liquid part, containing light suspended solids and matter in solution, is subjected to biological treatment to purify it before discharge, producing in the process a secondary sludge which is normally returned to the incoming sewage to settle with the raw sludge. The raw sludge may be treated by an anaerobic digestion process. Digestion takes place at normal temperatures in open tanks over a period of months, or within a few weeks if the sludge is heated in enclosed tanks. The process reduces the bulk and destroys the offensive smell of raw sludge. Methane gas produced during the fermentation can be tapped as a source of energy. The process also improves the properties of sludge as a fertilizer and is thought to reduce substantially the numbers of pathogenic organisms that are present in the raw material. We comment further on this latter point in paragraph 6.19. About one half of the sewage that is disposed of to land is produced by the larger treatment works which employ such an anaerobic digestion process. Apart from a small quantity of sludge which is digested solely by an aerobic process, the rest is disposed of without digestion although some of this receives other treatments designed to reduce bulk and improve handling properties. Such treatments may also reduce the numbers of disease producing organisms in the sludge. The figures shown against undigested sludge in Table 6.1 include raw sludge and sludge subjected to various kinds of treatment other than digestion.

The benefits and risks of sewage sludge on land

6.6. The main value of sewage sludge to agriculture lies in its content of the nutrients nitrogen and phosphorus. A third important nutrient, potassium, is present in sludges in only negligible quantities. The availability of the nitrogen in sludge for uptake by crops depends on the treatment process, being highest for liquid digested sludge, where a high proportion of the nitrogen is in solution as ammonium compounds, and lowest for raw sludge, where most of the nitrogen is held in organic compounds and is released slowly through microbial action. It has been suggested that this slow release offers advantages, especially by reducing the loss of nitrogen by leaching when sludge is applied to land in the autumn and winter. Sewage sludges are often dewatered and dried to give a solid rather than a liquid material and this results in some loss of nitrogen. The lime that is generally added to the sludge during this process may sometimes be of value for agriculture. The total proportion of nitrogen and phosphorus requirements that could be supplied by sewage sludge if this were all applied to agriculturally productive land amounts to about 5 per cent of the current use of these nutrients in inorganic fertilizers. The potential contribution is thus small but not insignificant.

6.7. Sewage sludge may also act as a soil conditioner by virtue of the organic matter it contains although its value in this respect is more difficult to assess. Concern has been expressed about deterioration in soil structure resulting from intensive farming, especially on light sandy soils, and about the very low levels of organic matter in some soils. It appears, however, that while very heavy applications of sludge may be beneficial from this viewpoint, normal rates of application, especially of liquid sludges, probably have little effect.

The risks from heavy metals and other contaminants

6.8. Sewage sludges, like soils, contain a wide range and concentration of metals and other elements, usually at low levels. Some of these elements (for example, copper, boron and zinc) are necessary in trace amounts for crops and animals but may have toxic effects at higher concentrations. Moreover, the margin between concentrations corresponding to deficiency and toxicity can be small. The amounts of these elements normally present in sludge are such that the possibility of toxic effects is likely to be a more important consideration than the correction of soil deficiencies. Other elements that have no known nutritional role and are commonly present in sludges (for example, lead, cadmium, mercury and arsenic) can be hazardous at relatively low concentrations. In addition to metals and other elements, sludges may contain chemical compounds harmful to agriculture. Some sludges contain persistent organochlorine compounds, for example, and some may be contaminated with residues from the manufacture of herbicides which could cause damage to crops. High concentrations of some metals in sludge derive from industrial effluents discharged to sewers; these could be significantly reduced in time by stricter controls on trade wastes. However, some elements, such as zinc and boron, are largely of domestic origin, (the main source of boron, for example, is domestic detergents) and significant reduction in the amounts present in sludge is unlikely. It is neither practicable nor economic completely to separate industrial effluents from sewage, moreover the removal of metals from sewage sludge prior to disposal is also not at present economically feasible.

6.9. The presence of these various substances, especially metals, in sewage sludge applied to land is of concern for several reasons. There is the possibility that they may have phytotoxic effects, that is, that they may damage plants and restrict their growth. They may be taken up by plants and thus enter food chains to animals and humans. Generally, heavy metals applied to the soil are not removed by leaching and are not taken up by crops. The repeated application of sludges containing these metals could, therefore, lead to the cumulative and effectively irreversible contamination of agricultural soils, with consequences that cannot be foreseen. Where sludge is applied to pasture, the substances it contains may remain in the surface layer and be directly ingested by grazing animals, which often consume substantial quantities of soil with herbage. Similarly, children may eat soil. For this and other reasons it is recommended in the DOE interim guidelines on the disposal of sewage sludge on land (see paragraph 6.23) that sludge should not be applied to gardens or areas where infants are likely to play.

6.10. An example of the toxic effects on grazing animals that may be produced by contaminants in sewage sludge is provided by a recently reported, severe case of fluoride poisoning in cattle. It is known that emissions of fluoride from certain industries to the atmosphere and the resulting deposition of the substance on the land can cause fluorosis in grazing animals and we comment further on this aspect in paragraph 6.50. Such airborne fluoride may also have been a factor in this particular incident but it has been accepted by the water authority concerned that a contributory cause was the unsuspected presence of very high levels of fluoride in the sewage sludge applied to the land. It has been stated that this position arose because of tighter controls applied by the pollution control authority involved, that is, the Alkali Inspectorate*, to industrial emissions of fluoride which then led to the substance being disposed of in effluent to the sewage system. If this were so, the case provides added support for proposals made in the Commission's Fifth Report([80]). In that report, the Commission argued that it was wrong in isolation to seek to reduce pollution in one form without considering the consequential effects on pollution in other forms, which might thereby be increased. The Commission recommended that a new pollution control inspectorate should be created which would be able to look comprehensively at all forms of pollution from major industries and to arrive at the "best environmental option" in seeking pollution abatement.

6.11. Much work has been done to assess the risks of harm to plants, animals or people through the addition to soil of metals or other potentially toxic elements present in sludge. Some elements, including zinc, copper and nickel, are toxic to plants in relatively low concentrations. For such elements, maximum allowable soil concentrations may be set at levels which ensure that soils remain productive. As far as human health is concerned, elements that are both toxic and cumulative in man, for example mercury and cadmium, pose greater hazards. Mercury is lost from the soil by biological means so that it does not accumulate; also, it is normally present in only small amounts in sludges and is not thought to be taken up appreciably by plants. Nevertheless, because of its high toxicity to animals and man, the amounts applied in sludge must be limited. Cadmium is the element of greatest present concern. It is very toxic to man and is taken up readily by plants. Natural levels of cadmium in the soil are very low so that quite small additions may be significant. There is, however, a lack of reliable data on which to base acceptable levels for the element in soils. Generally, the factors involved in assessing acceptable levels are complex and there are many gaps in knowledge. The effects on crops of metals in sludges vary with both the soil and the crop. More needs to be learned about the forms in which heavy metals occur in sludge and the ways in which they are transformed in the soil. The availability of metals to crops is affected by the content of organic matter in the soil and by soil acidity. There may be interactions between metals in terms of the effects they produce. It has been suggested, for example, that uptake of cadmium by crops is affected by the presence of zinc and that if the ratio of zinc to cadmium in the soil is

*HM Alkali and Clean Air Inspectorate, which forms part of the Health and Safety Executive, is referred to throughout this report in its abbreviated form: the Alkali Inspectorate.

sufficiently large, toxic concentrations of cadmium will be a lesser hazard. But where excessive amounts of cadmium are present in soils or sludges, the "compensating" amounts of zinc would themselves be phytotoxic. There are, therefore, considerable difficulties in establishing on a firm basis safe practices for the disposal of sewage sludge to agricultural land. However, some guidelines must be set for disposal practice and we discuss below those that have been promulgated by the authorities involved.

The risks from disease organisms

6.12. Another aspect of the use of sewage sludge on land is the possibility of health hazards due to disease organisms. Raw sewage often contains a variety of pathogens, including bacteria, viruses and parasites (in the form of eggs or worms of protozoan cysts) and although these organisms are substantially reduced in numbers by sludge treatment they are not completely eliminated. We return to this point in paragraph 6.19. The risks to health arise from the possibility that foodstuffs, or people working or playing on sludge treated land, may be contaminated by the organisms. There is a risk that pathogens may reach water courses by run-off from the land; they may also be transmitted by domestic and wild animals, by birds and by insects. They may be taken up by and infect grazing animals when sludge is applied to pasture. It should be noted that athough the survival of pathogens in the environment constitutes a potential disease risk, the extent of the risk depends on the characteristics of the organisms and on the numbers involved. Various factors affect the susceptibility of the host, whether animals or humans.

6.13. Among bacteria, the *Salmonella* group is probably the most important, being widely present in sewage. The organism can infect animals and humans if ingested in sufficient numbers and is often responsible for food-borne gastro-enteritis. The survival time of *Salmonella,* as of other pathogens, in sewage sludge deposited on land, depends on various factors including exposure to sunlight (which is strongly bactericidal). In the UK, *Salmonella* has been shown to persist on grass for periods ranging from 18 days to 24 weeks([84]). There is, however, no evidence associating outbreaks of animal salmonellosis in this country with the use of sludge on land, though there is some evidence of infection from contaminated water supplies([84]). Evidence linking sludge disposal to salmonella infection in cattle has been published in other countries. In recent years the pattern of salmonellosis in cattle and sheep in Great Britain has changed significantly. The reasons for this change are not fully known although it is thought that contamination in feeding stuffs is an important factor and that sewage effluent and sludge may be implicated.

6.14. The main risk to human health is from the contamination by raw sewage, or raw sewage sludge, of foods that are eaten uncooked or of milk that is drunk unpasteurised. However, the full extent of salmonella infection is not known and it is difficult to relate outbreaks of disease to the use of sludge. We noted that the number of deaths attributed to salmonella infections other than typhoid and paratyphoid fever among males of working ages (15–64 years) increased progressively from 3 to 4 a year in 1968/69 to 15 a year in 1975/76 and we think that the reasons for this should be investigated.

6.15. Direct links between sewage sludge disposal and human disease are even harder to establish with respect to contamination by viruses. A relationship has been established between epidemics of infectious hepatitis and the contamination of water supplies by sewage, and viruses causing this disease have been isolated from filter-feeding shellfish taken from sewage contaminated water. A potential hazard thus exists but more information is needed before this can be fully assessed.

6.16. The eggs of human parasitic worms and cysts of protozoa that inhabit the intestinal tract exist in sewage and may resist sludge processing. They constitute a potential health hazard but the extent of this is unknown as such infections are not notifiable and may be symptomless. The prevalence of one kind of parasite in humans, the tapeworm *Taenia saginata*, can be inferred from the incidence of infection in beef cattle, which are necessarily involved as intermediate hosts in the life cycle of the organism. Tapeworm infection is aesthetically unpleasant rather than a health risk. It has been estimated that an infected human may excrete up to 400,000 eggs each day([84]). The eggs are very resistant to adverse environmental conditions and can survive on pasture for five months or more([84]). If they are taken up by cattle, larvae are released from the eggs in the intestine and these migrate to the muscles where they form cysts, known as *Cysticercus bovis*. The cycle is completed if infected meat is consumed. Ideally, an infected carcase should be detected during meat inspection; it is then detained and frozen to destroy the cysts or, if heavily infected, it may be condemned. Either of these courses involves financial loss for the farmer. The view has been put to us that the methods for detecting cysts in carcases at abattoirs are inadequate for lightly infected carcases and that inspection procedures should be modified to ensure that animals grazed on land fertilized with sludge are more thoroughly examined. The cysts are destroyed by thorough cooking of the meat.

6.17. There is no doubt about the role of sewage sludge as a vehicle for the infection of bovine cysticercosis although there is as yet little firm evidence that infection is becoming more prevalent in the UK. An incident in which 36 out of 40 bovine carcases were found to be infected with *Cysticercus bovis*, and which was linked to the application of sewage sludge to pasture, was reported([85]) in Scotland. This was followed by a second incident in which 11 out of 45 carcases were found to be infected. It has been stated([84]) that many incidents in which a high infection rate is found are "thought to be associated with the excursions of motorists from lay-bys". Evidence of increasing infection has been reported in some other countries.

6.18. A further factor in the incidence of infection by human parasitic worms and protozoa is the ease of travel to and from areas of the world where such conditions are endemic. It is relevant in this context to note studies showing a high rate of infestation with intestinal parasites among UK schoolchildren who had recently been in tropical countries([86]). We think it is important to recognise the possibility that wider opportunities for travel may substantially increase the risk and incidence of infection in the population and to take this factor into account in policies for sewage treatment and disposal.

6.19. It has generally been considered that sewage treatment reduces the number of pathogens to a low level. In the Report of the Working Party on the Disposal of Sewage Sludge to Land([102]) it is stated that the number of disease producing organisms is "substantially reduced" by treatment and "drastically reduced, though not completely eliminated" by heated anaerobic digestion. There is, however, controversy on the matter and there are conflicting reports on the effectiveness of treatment; some research workers have reported that anaerobic digestion does not appear to eliminate *Salmonella* as has been assumed in the past. It appears that lime treatment, activated sludge treatment and unheated anaerobic digestion have little effect on tapeworm eggs though there is some evidence that the eggs do not survive the heated digestion process. The position is thus somewhat uncertain. There is a wide variety of treatment processes and of pathogens. Treatments that are effective against one organism may not be against another. The effectiveness of treatment may be affected by plant design and operation; results achieved on laboratory scale equipment may not be reproduced under field conditions. It appears that insufficient is known at present about the effects of different sewage treatment processes to provide a sound basis for determining sludge disposal policy from the viewpoint of the risks posed by pathogens.

Amenity problems due to sludge disposal

6.20. In addition to the risks posed by toxic elements and pathogens, the application of sewage sludge to agricultural land can cause amenity problems, chiefly those of odour. The smell created by the spreading of untreated sewage sludge is particularly offensive. Elsewhere in this report we discuss the need for guidelines relating to the disposal of animal waste in the form of slurry from intensive livestock units. We think that care to avoid nuisance problems is no less necessary for the spreading of sewage sludge.

Sludge disposal practice and policy

6.21. The return of sewage sludge to the land is attractive in principle in that it recycles nutrients that are necessary to plant growth. The practice is attractive to the authorities responsible for sludge disposal since it frequently offers the cheapest option. Nevertheless, at least at the present stage of knowledge, the balance of risk and benefit appears fine and this is reflected in the range of opinion that has been put to us on the matter. Generally, agricultural interests recognise the problems of sludge disposal faced by the water authorities and accept that the material has a modest value in terms of its nutrient content and as a soil conditioner. They are, however, naturally anxious about the possible risks posed to crops and livestock and they are concerned that because of the pressures to adopt the least expensive method of sludge disposal, there may be insufficient caution in expanding its agricultural use. Stronger arguments have been put to us. The Council of Scottish Agricultural Colleges (COSAC) commented on the tendency to regard land, including agriculturally productive land, as a "dustbin" for disposal of wastes where alternative methods are economically less attractive. The Council stressed that carefully controlled disposal of sludge to some land should be seen as being primarily in the national social and economic, rather than in the agricultural, interest and that there are long term risks in the process.

6.22. The general view of those organisations concerned with sewage treatment is that disposal of sludge to land is a traditional method and the cheapest, and that given that the material is applied sensibly with due regard to the potential risks from toxic constituents and pathogens, the practice is one of mutual benefit to agriculture and disposal authorities. It is acknowledged that excessive applications of sludge in particular localities in the past have rendered some areas of land useless for agriculture permanently because of the build-up of heavy metals. There are some small areas of "sacrificial" land where agricultural potential is deliberately sacrificed, the land being used solely for sludge disposal. The need for care in regard to the contaminants in sludge and the application rates used is accepted but it was represented to us that there is no evidence of any general harm from a practice which has been widely used for a very long time. It was also suggested that forestry might play a greater role in sludge disposal. The view of the Forestry Commission is that sludge is a useful source of nitrogen but that transporting it to forest sites is uneconomic: also, as conifers are sensitive to zinc, the heavy metal content and rate of application have to be controlled as for agricultural use. It is possible that local authorities could use sludge to reclaim derelict land as amenity woodland. The Forestry Commission is co-operating in some experiments but such sites are obviously limited.

6.23. Awareness of the risks posed by sludge, particularly from trace metals, has increased in recent years. In 1971, MAFF proposed maximum permissible levels for the phytotoxic elements zinc, copper, nickel and boron which would still permit the most sensitive vegetable crops to be grown([87]). These standards have been largely accepted in England and Wales but they provided no guidance for other elements. Early in 1974, DOE appointed a Working Party on the Disposal of Sewage Sludge to Land to prepare guidelines for safe disposal. Following the major reorganisation of the water industry in 1975, a Standing Committee on the Disposal of Sewage Sludge was set up jointly by DOE and the National Water Council (NWC) with sub-committees to investigate disposal to land, to sea, and by incineration and the economics of disposal. The working party was thus superseded by the relevant sub-committee and it prepared a handing-over report on its work to provide a basis for the investigations of the new body. The report([102]) was published in 1977 and it provides interim guidelines pending the preparation of a code of good practice by the sub-committee. This work is proceeding as an urgent matter.

6.24. The working party report concludes that the benefits of applying treated sewage sludge to agricultural land under proper control far outweigh any possible hazards. Guidelines are presented for application rates of sludges, designed to prevent an excess application of nitrogen (which may reduce crop yields and increase the risk of nitrate losses to water supplies) and to limit the total addition of metals to levels that are thought to be acceptable. The proposed limits for metals are presented in terms of the total dressings that may be applied over a period of 30 years or more. (An exception is boron, which, because of its solubility, does not build up to high levels in the soil. For this element an annual limit is set.) A limit is also proposed for the amount of an element that should be applied in any one year. The working party adopts the "zinc equivalent" concept, introduced in the earlier MAFF recommendations, which assumes that the phytotoxic effects of zinc, copper and nickel are additive and that nickel and copper are, respectively, eight times and twice as phytotoxic as zinc. We may illustrate the proposed limits by reference to that for cadmium. Soils probably contain on average less that 1 mg of cadmium per kg. The working party propose that no more than 5 kg of cadmium per hectare should be added over a period of 30 years or more. This would correspond to an addition to soil, cultivated to a depth of 20 cm, of 2·3 mg of cadmium per kg of soil.

6.25. The view has been put to us that the levels of potentially toxic trace elements that can be applied to agricultural land under the guidelines are unacceptably high. Most of the metals that are present in sludge will accumulate in the soil and repeated applications could lead to very heavy contamination and to soils with a composition quite unlike that of any that occur naturally. The process would be irreversible and might have future effects that could not now be foreseen. The allowable addition per hectare over 30 years of 1,000 kg of lead and 5 kg of cadmium could, for example, lead to 20-fold and 5-fold increases respectively in the levels of these elements in some typical, uncontaminated soils (assuming that these additions are dispersed to plough depth).

6.26. Concern about the possible effects of cumulative additions of heavy metals to the soil was expressed by COSAC. We were struck by the fact that the Scottish Office is preparing its own guidelines for sludge disposal to land, no doubt taking account of COSAC advice, and that these are likely to be more stringent than those of the DOE working party. It was put to us that this could be justified by different conditions that obtain in Scotland; for example, Scottish soils tend to be more acidic, which increases the possibility of uptake of heavy metals by plants. To the extent that such factors are important, however, we would think that they could be embodied in common guidelines. A better justification for stricter guidelines in Scotland perhaps stems from the fact that in the present state of knowledge any such guidelines must represent an uncertain compromise between agricultural and sewage disposal interests. In Scotland, the amount of sludge to be disposed of in relation to the land available is relatively small so that the application of stricter standards is feasible.

6.27. We referred in paragraph 6.19 to the working party's assessment of the efficacy of sewage treatment processes in destroying pathogens and this is reflected in proposed constraints on the use of treated and untreated sludges. The report proposes that where no odour nuisance will be caused, untreated sludge may be applied to land for the production of animal feed crops or for the production of crops which are always cooked before human consumption. Ploughing should take place after application. Land should not be used for grazing within a period of six months of application unless adequate monitoring for pathogens shows that a shorter period is acceptable. This period is reduced to three weeks for treated sludge but to five weeks where grazing cattle produce milk which is not to be pasteurised. Crops that may be eaten raw should not be sown until one year after the application of treated sludge to land. More stringent recommendations are made for specialist crops and for particular sludges.

6.28. Adoption of the guidelines implies substantial additional costs for some water authorities since metal contaminated sludges would need to be spread more thinly over greater areas of land. The Thames Water Authority, for example, indicated that while it broadly accepted the guideline for cadmium in the present state of knowledge, compliance would involve additional costs of £2m per annum. The Authority is strongly opposed to the proposed limits both for the rate of nitrogen application and for the addition of phytotoxic metals in terms of the zinc equivalent, considering that experience has shown that good yields of arable crops can be grown with sludge dressings that contain much higher levels of these elements. Some authorities have questioned the basis for the recommended delay periods referred to above. It has been noted, for example, that a requirement for a 12 month period between sludge application and the growing of crops that may be eaten raw would effectively rule out the use of sludge by vegetable farmers or market gardeners, who could not allow land to remain unproductive for so long. The six month delay before grazing is similarly disputed; some authorities believe three months to be sufficient and some, one month. The working party's views on the efficacy of sewage treatment, including anaerobic digestion, in destroying pathogens have also been questioned, in particular by the Yorkshire Water Authority. This Authority has vigorously promoted arrangements for the disposal of untreated sludge to agricultural land in its region, believing that many of the opinions previously held in the water industry on the potential risks to animal health of this practice cannot be supported or proven.

6.29. We have commented at some length on the proposals of the DOE working party and reactions to them in order to indicate the extent of the uncertainty that exists in this important area of public policy. These uncertainties can be resolved only gradually in the light of continuing research. The problems should not be overstated. We have noted that sewage sludge has been applied to land over a long period with benefit to farmers and with evidence of harmful effects in only a few special cases. One consideration behind the DOE working party guidelines is that under the proposed limits for the rate of addition of metals in sludge to soils, only about one fifth of the permitted total amounts would have been applied in six years. There would thus be ample time to tighten recommendations should the need to do so be indicated by research work that is now in progress. Moreover, sewage sludge is applied at present to only a small proportion of agricultural land. Disposal to land is, however, likely to increase. One factor that could well affect the position is increasing international pressure against the disposal of sewage sludge to sea. The UK disposes of a greater proportion of its sludge (about 28 per cent) by this method than any other country and a number of countries, including the USA and the Federal German Republic, have taken steps which could severely restrict sea disposal. In our discussion with the European Commission, concern about pollution of the marine environment by toxic elements in sludge was apparent. Another factor that seems likely to lead to increased disposal to land is that the reorganisation of the water industry has created authorities able to look comprehensively at the problems of sewage treatment in their regions and to organise such disposal on a scale that was not previously feasible. It is therefore increasingly important that the scientific basis for guidelines should be firmly established.

6.30. We have not investigated in detail the proposals made in the working party report on the disposal of sewage sludge to land. The proposals have been criticised, both for being unduly lenient and for being unnecessarily restrictive. The proposed interim guidelines appear to us to be generally sensible in the present state of knowledge; we have been influenced in particular by the point referred to above, that given the proposed limits on the rate of application of sludge with respect to its content of toxic metals, there would be time to take account of the results of further research before any appreciable build-up of levels in soils had occurred. It is important that the necessary research should be conducted and that the guidelines should be kept under continuing review. We consider that in view of the problems posed by toxic metals in sewage sludge, and the probably growing importance of land disposal, there is a need for greater efforts to reduce the contamination of sewage by industrial effluents.

6.31. The guidelines are not mandatory and, as we have noted, their adoption may pose difficulties for sewage disposal authorities. Indeed, we understand that some water authorities are not in a position at present to implement the guidelines that relate to toxic metals. We think that caution is needed in this area and that the authorities concerned should make every effort to adjust their policies to conform to the guidelines. We stress, too, the need for regular analysis of the levels of toxic elements in sludge and in soils to which sludge is to be applied, and for the maintenance of appropriate records. We accept the view put to us by MAFF that the costs of coordinated monitoring arrangements should be borne by water authorities as a legitimate cost of the disposal operation and that the results should be made known to appropriate departments within central government. Where information is obtained about significant contamination of agricultural land from past disposal operations, the relevant local authorities should be informed. It has been suggested to us by agricultural interests that water authorities should declare an analysis of the maximum metal content of sludge to the farmer before the sludge is spread so that he may, if he wishes, take independent advice on its likely effect; and, similarly, that the fertilizer value of the sludge should be identified. There may be technical difficulties in adopting these suggestions but we believe that they are right in principle and should if possible be adopted. It is important to instil confidence in the farming community that assessment of the benefits and risks of sewage sludge application is established on a sound scientific basis.

6.32. We think that insufficient consideration was given by the working party in its report to the possible risks posed by pathogens in sewage sludge, particularly with respect to the spreading of untreated sludge. Another deficiency that was brought to our notice was that the ARC had not taken part in the deliberations of the working party. This is the more surprising in view of the research projects that are in progress at several ARC institutes on the effects of heavy metal contamination on animals and plants. We think that steps should be taken to ensure appropriate representation of ARC expertise on the DOE Standing Committee on the Disposal of Sewage Sludge and on other relevant committees.

6.33. Our main anxiety on the question of sewage sludge disposal to land relates to the increasing practice of applying raw sludge and to the potential risks from pathogens to the health of humans and animals. The practice has been most actively promoted by the Yorkshire Water Authority which has produced a commendably thorough code of practice to ensure that its own operational staff involved, the specialist contractors who are employed and the farming community are fully conversant with the procedures to be followed. The Authority sought the views of local authorities in its region and of other interested bodies in preparing the code of practice. Nevertheless, some concern has been expressed to us that there are important shortcomings in the code with respect to the responsibilities of local authorities for public health and for dealing with problems of nuisance.

6.34. The Yorkshire Water Authority initiative rests on the desire to reduce the costs of sewage sludge disposal to a minimum and on the view that it is not necessary to digest sludge before spreading it on land. With regard to health risks, the Authority has pointed to growing evidence that some human pathogens are not destroyed by the digestion process as had previously been supposed.

6.35. In our view, however, it is one thing to argue that sewage treatment processes may not be as effective as previously thought in reducing the numbers of disease producing organisms in sludge but quite another, in the present state of knowledge, to proceed from this to any substantial commitment to raw sludge disposal for the future. Our view on this matter was further strengthened by our discussion with the European Commission in which surprise was expressed, on both aesthetic and health grounds, that such a policy was contemplated. We conclude that before such a step could properly be taken, much more needs to be learned about the effects of different treatment processes in reducing or eliminating pathogens and about the persistence of pathogens that can cause infection. We recommend that research on the extent of pathogen survival should be given greater emphasis in the total programme of research relating to sludge disposal to land to which we refer briefly below and that, pending the outcome of such work, the practice of spreading untreated sludge should not be extended. We hope that this matter will be considered fully by the Joint Standing Committee and that an agreed national policy will be evolved.

Research

6.36. A considerable programme of research is in progress or planned on the manurial value of sludges and on the problems caused by heavy metals, organic substances and disease organisms. We have not examined this programme in detail but we are broadly satisfied that, apart from research on disease organisms discussed above, it is adequate. The working party made a number of recommendations relating to research requirements, including a recommendation that a central organisation should be set up to coordinate work concerned with sewage sludge disposal. We fully support this recommendation which has been implemented by the formation of a working group of the Standing Committee to consider research needs and priorities.

6.37. A number of organisations are involved in the support of research relating to sewage sludge disposal, in particular the Agricultural and Environmental departments and the water authorities. In this field (as in others) there is a risk that necessary research may not be undertaken because it is accorded insufficient priority in the programme of each organisation; this may reflect a lack of clarity in the division of interests and responsibilities between them. In respect of sewage sludge disposal to land, the question arises of whether the practice is to be seen primarily as one that brings benefit to agriculture or as one that offers an economic means for the disposal of a waste. Bearing in mind the limited value of the material as a fertilizer and the risks attendant on its use, it appears to us that the latter is the dominant interest and that this should be reflected in the funding of relevant research. We note that the DOE has established an interdepartmental group to review its support for research into the disposal of sewage sludge in relation to that of other organisations and we hope that our view on this matter will be taken into account by this group.

Water supplies for agriculture

6.38. Water is used for various purposes on farms; these include the watering of livestock and the irrigation of crops. The demands of agriculture for water, particularly for irrigation, are likely to increase; the ACAH is currently undertaking a study of the future needs of the industry for water. The cost of a mains supply for agricultural purposes is sometimes uneconomic and water may be used from rivers and streams or from wells, ponds or boreholes. The number of farms depending on such sources seems likely to decrease but we were informed by the NFU that a census carried out in 1970 indicated that, at that time, some 30 per cent of farms used a private source of water. On a high proportion of farms, streams and rivers provide water for livestock when at pasture and these natural supplies may also be needed for fish farming enterprises. There are some special agricultural needs; for example, water used in dairies must conform to the requirements of the Milk and Dairies (General) Regulations 1959. Agriculture is thus vulnerable to pollution of water supplies by chemical contaminants or by disease organisms which originate in effluent from farms or domestic dwellings or from sewage treatment works and industry. We have accordingly enquired about the extent of the problems that exist in this area.

Risks from disease organisms and chemicals

6.39. There have been various studies on the presence of pathogens in water supplies and on their role in the transmission of disease. MAFF carried out a national survey of streams and rivers in 1975 which showed that *Salmonella* could frequently be found in them. Most of the serotypes isolated were of human origin, deriving from sewage works effluent, but some could be traced to poultry processing plants or to farms. The Ministry expressed the view that such water presents a greater disease risk to livestock drinking it than does the grazing of land contaminated with sewage or slurry. There have been a number of investigations under the Zoonoses Order 1975 which have incriminated water as a source of infection. An example is provided by an outbreak of *Salmonella paratyphi* B infection in cattle, due to contamination of a stream by sewage, in which the infection multiplied in the cattle and was distributed to many people, with serious consequences([88]).

6.40. There is some concern about health risks where water containing human pathogens, such as *Salmonella,* is used to irrigate crops that may be eaten raw. A somewhat extreme example which was mentioned to us occurred in the drought of 1976 when the public was admitted to a field of strawberries to pick the fruit while spray irrigation was in progress, the water being abstracted from a stream where almost all the flow consisted of an unsatisfactory sewage effluent discharge. Pathogenic bacteria in irrigation water tend to die fairly quickly when exposed to daylight on crops or soils, and there have been few reported cases of harm resulting to humans from this cause. We were informed by MAFF, however, that EEC proposals are possible which would call for the installation of some form of treatment plant by growers where necessary. The Ministry is at present studying various possible methods.

6.41. There have been occasional cases of injury to livestock as a result of the accidental discharge of chemicals from industrial sources into water courses used for drinking water, but these incidents have been of only local significance. Several bodies have commented to us on the risk of pollution of farm water supplies by leachate from landfill sites used for the disposal of wastes or by effluent from mines or quarries. While pollution from these sources may create problems, we note that control will be strengthened under the provisions of the Control of Pollution Act 1974 when fully implemented. Moreover, with regard to landfill sites, the results of a large DOE research programme on the threat posed to water supplies are generally reassuring and new criteria have been set for disposal of wastes on such sites which should avoid future risks to agriculture.

6.42. Chemical pollution of water supplies may also affect crops. A notable example is provided by an incident which occurred in 1973 when tomato plants grown in greenhouses in Essex were severely damaged through the presence of minute quantities of a herbicide (trichlorobenzoic acid or TBA) in the water used to irrigate them. Some damage to tomato plants in subsequent years was attributed by growers to residual contamination of soils but this was not confirmed. The herbicide had been discharged into a river in Cambridgeshire from a pesticide manufacturer's works. The level of the chemical in the effluent was within prescribed limits and the discharge had been made for some years. The damage occurred because of new circumstances in which water was transferred to the Essex river system in order to augment supplies in that region. Tomato plants are extremely sensitive to certain herbicides and are in fact used by some water authorities in laboratory tests to detect the presence of trace amounts of these chemicals in water. Steps were quickly taken to reduce the discharge and new treatment facilities were subsequently introduced by the firm concerned. We were informed that the conditions now applied to the discharge ensure adequate protection for tomato growers.

6.43. The case is clearly exceptional but it highlights the care that is needed in assessing the possible effects of even trace amounts of some chemicals in industrial effluents and in considering the new uses to which water may be put as a result of inter-river transfer schemes. Incidents of this kind should obviously be investigated thoroughly by the authorities involved, principally the water authorities and ADAS, and we do not doubt that this was done in this particular case. As a general point, however, we think it is important that all reasonable steps should be taken to allay the anxieties of people whose livelihood may be affected, on the possibility of longer-term, residual effects.

6.44. As another example of chemical pollution, there has been some concern over the possible phytotoxic effects of boron which is present in sewage effluent because of its use in synthetic detergents. We were informed that only one case of damage has been reported. Glasshouse crops are particularly vulnerable because of the amounts of water they receive and the DOE Standing Technical Committee on Synthetic Detergents has recommended that, in the main glasshouse areas, water authorities should monitor the boron content of river water which may be used for irrigation.

6.45. We have concluded that although continuing care is needed in a number of areas, pollution of farm water supplies does not constitute a serious problem. The NFU expressed the belief that the agricultural industry may be suffering unquantifiable losses in terms of reduced livestock performance and fertility due to polluted water supplies. No doubt there are some such losses but we have seen no evidence to suggest that they are significant. There seem good grounds for thinking that such problems as exist will diminish rather than increase. In particular, the water industry reorganisation has created (in England and Wales) authorities with much greater resources for the control and monitoring of discharges and with improved scientific facilities. Attention is likely to be further concentrated on these matters by EEC developments. The European Commission is considering the preparation of a Draft Directive, under the Community's Environmental Action Programme, on the quality of water for use in agriculture.

Air pollution and agriculture

6.46. The Commission considered the arrangements for the control of air pollution in its Fifth Report([80]) and made a number of recommendations for changes in these arrangements, some of which have a broad relevance to the question of the impact of such pollution on agriculture. In the context of that general study, however, the Commission was unable to deal specifically with agricultural aspects. We decided that we should enquire into this matter further in our present study, the more so since it is clearly one of much concern to agricultural interests.

The effects of air pollution on agriculture

6.47. We are primarily concerned with the effects of industrial emissions, which may damage livestock or crops. These effects are most pronounced in localised areas surrounding particular kinds of industrial plants, where damage can be severe. More widespread, if less apparent, effects may be produced by the general levels of pollutants in the atmosphere which cannot usually be attributed to particular sources.

6.48. It appears that relatively little is known about the total losses to agriculture that may be ascribed to air pollution. The NFU informed us that it believed the effects of pollution on agriculture had been largely overlooked in the past and this view was corroborated by a comment made to us by DOE that there has been no systematic investigation of the possible detrimental effects of air pollution on agriculture. The point is of some importance. Policies relating to the location and development of industries and to the control of the air pollution they may generate imply a weighing of the costs and benefits: it is more likely that agricultural considerations will be given due weight if they can be placed on a quantitative basis.

6.49. The NFU provided us with a list of recent examples of adverse effects from industrial emissions which is reproduced as Table 6.2 (a few of the examples relate to other forms of pollution). These are cases which were brought to the Union's attention, often where compensation was paid; the list is by no means comprehensive and is intended only to be illustrative of the range in the nature of the effects and in their geographical spread. The list

TABLE 6.2
Survey of recent instances of the effects of industrial emissions

County	*Agent*	*Emission and Effect*
Kent	1. Power station (modern) 2. Cement works 3. Motorway const.	Smuts on edible crops—£60,000 compensation paid Dust—edibles and flowers—glasshouses Dust— ,, ,, ,, ,,
Hampshire	1. Oil Refinery	Fall out particularly on glasshouses
Somerset	1. Chemical Factory 2. Quarries	Hormone weedkiller affecting tomatoes—£4,000 Dust on fruit crops
Gloucestershire	1. Chemical Factory 2. Metal Works	Gaseous pollution affecting cattle—deaths and compensation Heavy metal contamination
Monmouth	Chemical works	Signs of pollution affecting livestock
Oxford & Berks.	1. Air bases 2. Brickworks 3. Power station 4. Chromate	Noise and fuel fall out from jet planes Heavy pollution—Fluorine and SO_2 Oil pollutants in drinking water for livestock River Thames
Bucks	1. Brickworks	Fluorine and SO_2 affecting crops and livestock
Beds & Hunts	1. Brickworks 2. Straw processing works	Fluorine and SO_2 affecting crops and livestock Noise
Essex	1. Cement works 2. Aggregate works 3. Trains	Dust emissions ,, ,, Dust from brake blocks affecting glasshouses
Lincolnshire	1. Aircraft 2. Chemical works 3. ,, ,,	Fall out and noise Flixborough—before and after Emissions causing scorching of crops and scouring
Nottinghamshire	1. Coal mining 2. Power Stations	General, also waste reclamation Increased moisture in the vicinity of the cooling towers, which has been detrimental to grass conservation and the harvesting of cereals.
Derbyshire	Quarries	Dust contamination
Staffordshire	1. Potteries 2. Sewage deposits	Fluorine Salmonella
Shropshire	Aluminium works	Gaseous fallout affecting farmer and his workers and stock.
N.R.—Durham	Petro-chemical plant Industrial plant	Fluorine Heavy metal contamination

Source: National Farmers' Union of England & Wales.

relates to cases where acute effects were apparent and the Union noted that many of the effects of pollution on agriculture are "sub-clinical" and therefore pass largely unnoticed.

The effects on livestock

6.50. One of the main examples of damage to livestock by air pollution has been the effect of fluorine compounds emitted by certain industries, including brickworks, steelworks and potteries. The compounds may be deposited on herbage and ingested by grazing cattle. Prolonged ingestion of excessive amounts can cause fluorosis, a condition characterised by damage to the teeth and bones and, eventually, by lameness and inability to feed. The problems of fluorosis in cattle were considered sufficiently serious in the 1950s for a study of the occurrence of the disease to be undertaken by MAFF. The report([103]) commented that the total economic loss due to fluorosis in livestock is not great compared with that caused by the major diseases but is a matter of serious concern to farmers whose stock is affected. We were informed by MAFF that the problem of fluorosis due to air pollution has declined (but see paragraph 6.10); only 12 cases have been reported to the Ministry in the past five years although some cases may be dealt with by local agreement between farmers and the industries concerned. The improvement is attributed to changes in the emitting industries, although the brick industry remains a source of this form of pollution, and to the adoption by affected farmers of kinds of husbandry that are compatible with the fluorine hazard. Another factor is that some larger industries have purchased agricultural land around their works, presumably so that they may exercise some control over the farming systems adopted and limit the problems caused by emissions.

6.51. Animal health problems may also be caused by other aerial pollutants, for example, by emissions of lead, zinc or cadmium from smelting industries. These problems do not appear to be large. Lead emissions from traffic could affect cattle grazing on pastures close to major roads. The NFU expressed concern on this point and referred to research which concluded that the concentrations found present no immediate hazard to cattle but that further work is needed. MAFF stated that industrial and urban emissions are at present of only marginal significance for the health of livestock and we have received no evidence that refutes this view.

The effects on crops

6.52. The effects of air pollution on crops may be of two kinds. There is the possibility of contamination of food crops which may pose health risks to humans or animals and there is the possibility of adverse effects on plant growth so that crop yields are reduced. The main effect that has been observed in terms of health risk is the contamination of crops by the emission of metals such as lead and cadmium from large smelting plants. Considerable quantities of these metals may be deposited at distances of up to a few kilometres from the plants. Lead from vehicle exhausts also contaminates crops growing near to major roads. MAFF has a direct responsibility to carry out monitoring to ensure that risks to humans or animals from such effects are avoided. Much of this monitoring is undertaken by Ministry officials working with Environment Health Officers and industry in local liaison committees. We were assured that generally the contamination of food does not reach unacceptable limits.

6.53. Air pollution may damage crops in various ways. The deposition of soot or dust can affect plant growth by reducing the rate of photosynthesis. Severe damage by dust can be caused during motorway construction such that crops may be made unsaleable or pasture unusable. Dust damage also arises from quarrying, open-cast mining and cement manufacturing. Dust deposits can lead to crop losses in glasshouses. We were informed that these effects occur on a quite considerable scale but they are localised and apparent. Visible damage to crops may be caused by high levels of gaseous pollutants in areas around emitting industries although the pollutants involved and their source may be difficult to establish. In terms of the total impact of air pollution on agriculture, most interest attaches to the possible effects of gaseous pollutants which are commonly present in the atmosphere, particularly sulphur dioxide.

6.54. Sulphur dioxide (SO_2) and other gases, including oxides of nitrogen, are emitted into the atmosphere in substantial quantities through the combustion of fossil fuels. Total UK emissions of SO_2 currently amount to about 5 million tonnes/year, compared with about 6 million tonnes/year at the end of the last decade. Concentrations of SO_2 in the atmosphere vary considerably depending on climatic conditions and other factors; there is a seasonal variation especially in urban areas, the concentrations being higher in winter months. Concentrations have generally declined since the early 1960s; in urban areas, annual mean concentrations are mostly in the range 30–125 microgrammes per cubic metre (or $\mu g/m^3$); at rural sites they are nearly all in the range 20–60 $\mu g/m^3$ (but see paragraph 6.64). Removal of the SO_2 from the atmosphere takes place by dry or wet deposition, the former referring to the absorption of the gas by plants, soil or water, or the direct deposition of sulphate in particulate form, and the latter to the so-called "acid rain" of sulphurous and sulphuric acids.

6.55. At sufficiently high levels, of the order of 400 $\mu g/m^3$ or more, SO_2 can cause visible damage to plants but such concentrations are very rare and occur only close to major urban or industrial centres for short periods of time. The effects on crops of the levels of SO_2 that generally occur in rural areas are more difficult to establish. Some time ago the ARC set up a group to consider the economic loss attributable to crop damage by air pollutants as a basis for assessing whether a more stringent control of emissions was justified. The conclusion reached was that while adverse effects on crops could well occur at levels of air pollution that caused no obvious signs of damage, their extent could not be separated from the effects of other variables affecting growth such as rainfall, temperature and disease. It was decided that a major research activity was not justified. More recently, further study of the effects of SO_2 has been stimulated by the concern that ecological damage in Southern Scandinavia might be caused by the deposition of sulphur compounds originating from emissions in the UK and other countries in Europe. An OECD study([89]) investigated the transport of airborne sulphur compounds and parallel work on the consequences of increased sulphur deposition on the natural environment was clearly required.

6.56. Growing plants need some sulphur and the deposition of atmospheric SO_2 can benefit crops grown on sulphur-deficient soils. There appears, however, to be much uncertainty about the general extent to which such beneficial effects may occur. Various factors are involved including the rate of deposition of sulphur, the extent to which sulphur is leached from the soil, the needs of the crops and the fact that, because of changes in fertilizer formulation, much less sulphur than hitherto is now added to soils as an incidental result of fertilizer application. It has been stated([90]) that although sulphur deficient soils are rare in the UK, many soils, even in polluted areas, contain only a small reserve of sulphur which is available for plant growth; and that if the input from the atmosphere and from rain were to decrease significantly, applications of sulphur fertilizers might be needed for adequate growth of some crops. A view, expressed to us in evidence from the Central Electricity Generating Board (CEGB), is that if SO_2 pollution of the rural atmosphere were to be reduced significantly, sulphate supply would be below crop requirements in large areas. In subsequent evidence, however, the Board acknowledged that while this view fairly reflected calculations of total sulphur supply and requirement, it did not take account of topographical and seasonal variations which would determine the extent to which a matching of these factors was actually realised.

6.57. In contrast to the above, the ARC estimated that current SO_2 pollution provides sulphur to the extent of about three times crop needs and expressed the view that a reduction in concentrations would be beneficial. The Council stressed that it was not known what the effect would be of a reduction in the environmental input of sulphur in rendering soils sulphur deficient.

6.58. Recently there has been more emphasis on the effects of relatively low levels of SO_2. In most such work, observations are made of the growth of plants in enclosures with differing concentrations of pollutants. There are considerable difficulties in interpreting the results. A major problem is that the conditions maintained in the enclosures will generally differ from normal conditions in other respects than pollutant concentration. There may, for example, be differences in temperature, humidity or soil moisture content which would affect the relative growth in the two environments, making it difficult to distinguish effects that are due to differences in pollutant levels. Moreover the sensitivity of a plant to SO_2 pollution varies during different stages of its growth; sensitivity may also vary between different varieties of a particular plant or even between plants of the same variety.

6.59. Such complications may account for the fact that experiments involving the prolonged exposure of plants to relatively low concentrations of SO_2 have yielded apparently conflicting results. For example, a trial on a type of rye grass showed a 52 per cent reduction in yield when the plants were exposed for 26 weeks to air containing 191 $\mu g\ SO_2/m^3$; another trial gave a 68 per cent reduction in yield with air containing 43 $\mu g\ SO_2/m^3$ ([91]). In another experiment in which the same type of rye grass was exposed for 59 days to air containing 131 $\mu g\ SO_2/m^3$, rapid growth occurred and no loss of yield was observed([92]). Tests conducted at the Grassland Research Institute have provided some evidence that prolonged exposure to air containing about 50 $\mu g\ SO_2/m^3$ may improve yields in grass grown on sulphur-deficient soils([93]).

6.60. More research is needed to improve understanding of these effects. Nevertheless, there appears to be some evidence that significant crop yield losses may occur as a result of levels of air pollution that cause no visible damage. Recent research by the ARC Rothamsted Experimental Station([94]), conducted at a site near to the Bedfordshire brickworks, has suggested that yields of barley (which is the largest acreage crop in England and Wales, apart from grass) may be reduced by as much as 40 per cent by the effect of pollutants, principally SO_2 in concentrations in the range 75–100 $\mu g/m^3$ but including fluoride and some other substances. These results must be interpreted with caution; the role played by the other pollutants present is unclear, moreover the results relate to a limited number of growing seasons (in two of which—1975 and 1976—the climate was unusual) and it appears that the results from the 1977 season showed no loss of grain yield, though straw yield was reduced. The experimental techniques employed need to be further validated. Moreover we were informed that similar research in other countries has not shown these dramatic effects.

6.61. Other recent research([95]) has indicated the possibility of synergistic effects on crop yields by the combined action of common air pollutants, in this case SO_2 and nitrogen dioxide (NO_2). The latter is produced by combustion processes. The technique used in this work is of some interest in that it attempted to reproduce in the laboratory conditions comparable to those encountered outdoors. The air in the chambers containing the plants (four commonly sown pasture grasses) was stirred and the pollutants were introduced intermittently. The weekly mean SO_2 concentration was 195 $\mu g/m^3$ and that of NO_2 was 140 $\mu g/m^3$. The results showed evidence of synergism; that is, the effect on yield of a mixture of the gases was markedly greater than the sum of their effects acting separately.

Research

6.62. Further officially sponsored research on the effects of air pollution on crops is continuing in several areas. The DOE is currently spending about £0·1m per annum on research which includes work on the effects of pollutants, principally SO_2, on the growth of coniferous trees in Scotland and on yields of two important crops, barley and rye grass. The work on trees, which is also partly funded by the EEC and NERC and is being done by the NERC Institute of Terrestrial Ecology (ITE), is relevant to the question of whether transported SO_2 causes environmental damage in Scandinavia. NERC is also sponsoring a number of other projects, at its institutes and in universities, on the effects of air pollutants on trees and plant life; the project referred to in paragraph

6.61 is an example. The work on rye grass referred to above is a collaborative project with MAFF and the ARC. These bodies also supported the work referred to in paragraph 6.60. MAFF informed us that this work was to continue during 1978 and that the possibility of extending it was to be considered for 1979.

6.63. We have not attempted a full survey of relevant work. Our main concern has been to try broadly to assess whether the general scale of research is commensurate with the potential importance of the effects of pollutants on crop yields. In considering this point, we first note that research may be directed either to assessing the impact on agriculture of the relatively high levels of pollution that arise near to industrial areas or to particular kinds of industries; or to obtaining a measure of the impact of chronic low level air pollution on agriculture, which would imply an attempt to assess the effects of the relatively low pollution levels that apply generally in rural areas. Research of the first kind might yield information which would affect policies for the control of emissions affecting particular localities. Research of the second kind might also affect control policies, but at the national level. It might also, however, provide information that would affect action in other areas; it might, for example, affect priorities for plant breeding, encouraging the development of varieties better able to withstand the effects of pollutants. For the reasons discussed below, we are not convinced that sufficient thought has been given to the underlying aims of the present programme of sponsored research, with this distinction in mind.

6.64. In paragraph 6.54 we quote a range of 20–60 $\mu g/m^3$ within which fall most mean annual values of SO_2 concentrations in the atmosphere at rural sites. This range is derived from results obtained over the last few years at sampling sites of the National Survey of Smoke and Sulphur Dioxide which is coordinated by the Warren Spring Laboratory (WSL) of the Department of Industry. The National Survey was designed to monitor the effectiveness of measures taken under the Clean Air Act to improve urban atmospheres and there are few rural monitoring sites; many of those that exist are atypical since they were set up to monitor the dispersal of pollutant gases from power stations. There is thus some doubt about rural mean concentrations. The WSL publishes at intervals a map showing the distribution during winter months of SO_2 concentrations; the latest edition of this map (for 1975/1976) suggests that the level of $50 \mu g/m^3$ is unlikely to be exceeded in the main crop and grass growing areas. The WSL expressed the view that no significant change in the present picture of the distribution of SO_2 concentrations would result from additional monitoring sites or a redistribution of existing ones. We note, however, that the DOE is setting up a small network of sampling sites in rural areas at which a number of air pollutants will be measured to establish trends in rural environments.

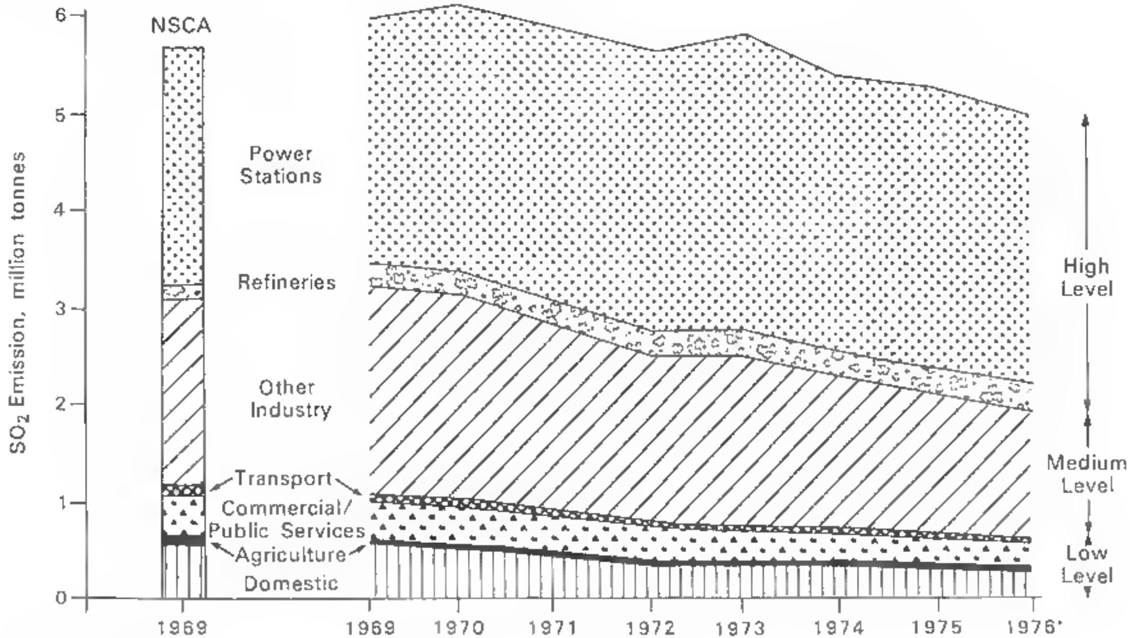
6.65. It might be thought that the adoption of the "tall stack" policy, and thus the wider dispersal of emissions from urban areas, would cause an increase in pollutant concentrations in remote rural areas. The WSL considers, however, that the concentrations in such areas are related to total emissions and are unlikely to be affected by change in the proportions of low-level to high-level emissions. Figure 6.1 shows that over the period 1969–76 total emissions declined by about 17 per cent but high level emissions increased by about 8 per cent. Measurements of SO_2 concentrations at remote rural sites over the same period showed no discernible trend at all either up nor down([96]). Closer to the sources of emission, those at medium and low level have a stronger influence on atmospheric concentrations. Emissions from small country towns are almost entirely in this category. During 1969–76, medium and low level emissions fell by nearly 40 per cent ([97]) and during that same period WSL SO_2 concentrations recorded at the rural sites of the National Survey fell by about 23 per cent. Over the next few years, WSL foresee a continuing decline in medium and low level emissions and little change in high level emissions. Thus in general, SO_2 concentrations at agricultural sites close to urban communities will fall still lower; at more remote sites, concentrations will remain at their present low level (below 30 $\mu g/m^3$). In the longer term, the trend in total emissions is problematical since it depends on various factors including economic growth and the demand for electricity.

6.66. All this suggests that while experiments of the kind described in paragraphs 6.59–6.61 may be useful in considering the impact of high emissions in particular localities (such as the area of the Bedfordshire brickworks) and hence in assessing the emission controls that should be applied to particular industries, they have little relevance to the problem of assessing the total effect of emissions on agriculture. The WSL commented that the experimental conditions used in these projects bore little resemblance to conditions that might be found in an agricultural area; for example, even in a typical urban environment, a concentration of 190 $\mu g\ SO_2/m^3$ would be measured perhaps during two days in each winter month and the probability of it being maintained for 26 weeks is negligible. Likewise, the experimental concentration of NO_2 quoted (140 $\mu g/m^3$) should be compared with the median concentration found in Central London (60 $\mu g/m^3$) and at Harwell, in rural Oxfordshire ($<20\ \mu g/m^3$).

6.67. Another matter of interest is the relationship between DOE and MAFF in supporting research in this area. The DOE priorities for research reflect its general responsibilities for pollution, exercised through its Central Directorate on Environmental Pollution (CDEP), and its specific concerns with air pollution, water supply, land use and nature conservation. In the Department's view, the main responsibility for research on the effects of air pollution on agriculture, as for research in agriculture generally, rests with MAFF (or DAFS). In view of the magnitude of the effects suggested by some research projects, it might be expected that work in this area would be regarded as a matter of some importance. We were therefore surprised to find that the current MAFF expenditure on such work is so small: it amounts to only about £20,000 per annum, largely in respect of the work described in paragraph 6.60. We recommend that this matter should be reviewed by MAFF

Figure 6.1

Sulphur Dioxide Emission by type of Fuel Consumer 1969–1976



*provisional figures

NSCA = figures published by the National Society for Clean Air

SOURCE: Warren Spring Laboratory

Plate 6.1. Refuse dumped in a field grazed by cows.

Photograph by courtesy of The National Farmers' Union.

in conjunction with other departments and organisations involved and taking into account the factors discussed above.

Other forms of pollution affecting agriculture

6.68. We have discussed above the main impacts of pollution from urban and industrial sources on agriculture. There are various other ways in which pollution may affect agriculture, causing damage which is generally localised though it may be very serious to the farmers concerned. Examples that have been mentioned in evidence are the transmission of disease to cattle through the scavenging of sewage and refuse tips by birds and vermin; and damage caused through highway spillages of toxic chemicals, or the breaching of sewers or pipelines, with resulting contamination of water supplies. The NFU noted, with respect to spillages, that the hosing down of roads after accidents involving chemicals in order to clear the roads quickly led to a spread of contamination. The Union expressed the view that more could be done to contain spillages and to minimise their environmental effects. We have received no information about the number of incidents or the extent of the damage they cause but if these are significant, we think that the arrangements in force to deal with such spillages should be reviewed to access whether potential risks to agriculture are taken sufficiently into account.

6.69. We referred earlier to the risks of harm to agriculture due to chemicals in water supplies. Agriculture may be affected by chemicals in other ways, which may be difficult to foresee. An example of this is provided by chlorophenols, which are used to protect timber from fungal attack. The highest concentrations occur in the surface layers of the timber and hence in the shavings or sawdust, which are used as bedding in broiler houses. Chlorophenols are converted by the action of fungi, which develop in the broiler house litter, into highly volatile derivatives known as chloroanisoles. The chloroanisoles are not toxic but they have an unpleasant, musty smell and even though they are present in the litter at only extremely low concentrations, they can taint the flesh of the birds that inhale them. A similar example is provided by the use of organochlorine pesticides such as dieldrin to protect timber from other kinds of pest attack. This has resulted in the loss of breeding poultry and to the contamination of hatching eggs and loss of fertility.

Agricultural problems in the urban fringe

6.70. Finally, we comment on a matter which, although in some respects outside our remit, is of such evident concern to farming bodies that it could not be omitted from an account of environmental factors that may damage agriculture. Farming on the fringe of urban areas is subject to particular problems: these include damage due to trespass or vandalism; the dumping of rubbish, which may not only cause great inconvenience but may damage machinery or harm livestock; and the stealing of crops or worrying of livestock. It is clear from the evidence we have received that the extent of these problems is serious and lamentable. MAFF provided some data on the incidence of damage from trespass, taken from surveys conducted by ADAS in the Slough/Hillingdon area (1973)([98]) and in the Metropolitan County of Tyne and Wear (1976),([99]) as shown in Table 6.3.

6.71. Other studies have confirmed this picture in other areas. The NFU referred to the results of surveys undertaken by the Hertfordshire County Council in the Barnet, Watford, St Albans and Potters Bar areas, and of a study in Essex, in which the proportion of farms sampled that reported a substantial rubbish dumping problem ranged from 33 to 71 per cent. MAFF

TABLE 6.3

Type of damage	% of holdings affected Slough/Hillingdon	Tyne and Wear
Crops damaged/stolen	35	52
Rubbish dumping (risk to machinery)	32	37
Damage to fencing and gates	27	24
Damage to farming equipment and general vandalism	15	22
Livestock worrying by dogs	10	40

commented that farmers had been forced by the damage problem to change their farming practices; for example, crop rotations had been altered and sheep, beef cattle and potato production reduced or discontinued.

6.72. It is easier to state the problems than to propose remedies. One area in which official action can help to ameliorate the problems is that of rubbish dumping. Several bodies have suggested that those local authorities which do not already do so should provide facilities where people can dispose of rubbish at convenient times, such as weekends; that portable bins might be used for this purpose on authorised sites close to village centres; that there should be no dissuading charge for the collection of bulky items which are too large to be collected with normal household refuse; and that the official tipping facilities that are already available for public use should be better advertised. These appear to us to be sensible proposals.

6.73. It is clear that the problems that beset agriculture in the urban fringe cannot be more than partially solved by legislation. One approach is to try to bring about a better understanding among the urban population of the facts of farming; for example, MAFF is co-operating with the Countryside Commission in encouraging demonstration farms where public access is allowed for studies of farming practices. The extent of the urban fringe, and the vulnerability of farming to abuses of the kind described above, are affected by the policies adopted for urban development. For example, a sprawling development may effectively degrade a much larger area of land than that used for a new settlement. We comment further on this point in paragraph 7.18.

CHAPTER VII

PLANNING AND RELATED MATTERS

Introduction

7.1. Agriculture enjoys considerable exemptions under planning law and we have considered whether this situation is satisfactory from the pollution viewpoint bearing in mind the changes that have occurred in farming practices. We are concerned with practices which may cause odour problems and pollution of water supplies and especially with intensive livestock units. In this context, we have also considered fish farming; there appears at present to be some doubt about whether fish farming comes within the scope of normal planning control or whether it is covered by the agricultural exemptions.

7.2. The polluting potential of agricultural developments, as of those in other industries, is affected by function, siting and design and, subsequently, by the quality of management, operation and maintenance. Planning control should ensure that development is so designed that, given good operating practices, the risk of pollution is reduced to an acceptable level. It might be desirable, as an aspect of this control, to provide for prior consultation with authorities, for example, local or water authorities, whose interests might be affected by pollution caused by the proposed development. But it is debatable (and we discuss this below) whether it is feasible and proper to seek to reduce the risk of pollution due to poor operational practices by imposing constraints on such practices as a condition of planning consents. An example of an agricultural practice where planning constraints might be considered desirable on environmental grounds is the application to land of slurry from intensive livestock units. A related question is whether the means that exist under pollution control legislation to prevent pollution caused by bad practices are adequate. In this chapter we consider the planning issue in the context of the total means that are available to ensure that appropriate agricultural developments are soundly conceived and operated from the pollution viewpoint.

Agriculture and planning

Development control

7.3. The use for agriculture of land or building occupied with the land is not classed as "development" for planning purposes under the Town and Country Planning Act 1971. This statutory provision does not cover new agricultural buildings, structures or erections but further exemption is provided under the Town and Country Planning General Development Order 1977 (SI 1977 No 289) which in Schedule 1 sets out in detail the classes of development for which planning permission is granted by the Order itself under article 3. Class VI of the Schedule, relating to agricultural buildings, extends exemption to the following:

> "The carrying out on agricultural land having an area of more than one acre* and comprised in an agricultural unit of building or engineering operations requisite for the use of that land for the purposes of agriculture (other than the placing on land of structures not designed for those purposes or the provision and alteration of dwellings), so long as:—
>
> *(a)* the ground area covered by a building erected pursuant to this permission does not, either by itself or after the addition thereto of the ground area covered by any existing building or buildings (other than a dwellinghouse) within the same unit erected or in course of erection within the preceding two years and wholly or partly within 90 metres of the nearest part of the said building, exceed 465 square metres;
>
> *(b)* the height of any buildings or works does not exceed 3 metres in the case of a building or works within 3 kilometres of the perimeter of an aerodrome, nor 12 metres in any other case;
>
> *(c)* no part of any buildings (other than moveable structures) or works is within 25 metres of the metalled portion of a trunk or classified road."

7.4. Generally speaking, therefore, a new agricultural building that is not additional to existing buildings is exempt from planning control if it is less than 12 metres (40 feet) in height and covers an area of less than 465 square metres (5,000 square feet). Where the new building is an addition to existing buildings within the same unit, it is still exempt if the latter were erected two or more years previously or are separated from it by a distance of 90 metres (100 yards) or more. Otherwise, the areas covered by the existing buildings must be taken into account. One of the things that concerned us was that, in theory at least, there is the possibility that the size of an intensive livestock enterprise could be increased by the addition at two-year intervals of buildings of up to 465 square metres in area without requiring planning permission.

7.5. These criteria appear mainly to have stemmed from concern with the impact of agricultural developments on visual amenity and countryside conservation rather than with pollution considerations. Our interest is in the latter although some of us accept a view put to us in evidence that on aesthetic as well as pollution grounds all farm buildings should be brought under planning control. A key condition for exemption from control is conveyed by the phrase: "requisite for the use of that land for the purposes of agriculture". The intention of that condition is clear in relation to traditional farming practices but it is not obvious how it should be interpreted in relation to intensive livestock units.

*The use of "acre" is apparently still maintained in the GDO in spite of the change to metric units elsewhere.

7.6. We were informed by MAFF that this condition was taken to mean, strictly, that to qualify for exemption from planning control, intensive units would need to form part of farms that are wholly self-sufficient in that they produce all the feedstuff required by the livestock; but that, in practice, the condition has been accepted as requiring that at least 35 per cent of the feedstuff should be produced on the holding. DOE referred to the matter of the amount of feedstuff produced on a holding as being a determinant of whether an intensive unit development would be regarded as industrial rather than agricultural in character. The Department commented that if a unit is not supported by the holding to the extent of "the bulk" of the feedstuff (which would suggest a greater proportion than the 35 per cent referred to above) it would probably not be regarded as an agricultural use of land and that a trend towards intensive units depending on bought-in feedstuff could bring more of these units within the planning system.

7.7. The difficulty of interpreting "requisite for the use of that land for the purposes of agriculture" in relation to intensive livestock units perhaps accounts for the differences that appear to exist in opinions on the extent to which the development of these units already requires planning permission. Thus, we were informed by planning authorities in the Humberside Region that they regarded all such developments as requiring permission, in contrast to the DOE and MAFF interpretations described above. We think it is unsatisfactory that there should be scope for such differences in interpretation on this point. Moreover, as we discuss further below, we do not consider that a condition relating to the proportion of feedstuff grown on a holding provides a satisfactory basis, at least from the pollution viewpoint, for deciding whether an intensive unit development should be subject to planning control. Such a condition is difficult to apply and almost impossible to monitor; there is no guarantee that it will continue to be observed during the period of use of a building.

7.8. The general view of agricultural interests is that the present system of development control as applied to farm buildings achieves a reasonable balance between the needs of the farmer and of the planner and that the degree of freedom enjoyed by agriculture is appropriate to the fundamental importance of ensuring the nation's food supply. It is pointed out that exemption applies only to the smaller buildings and that under the terms of the General Development Order relating to the timing of a development and to separation from other structures, many farm buildings, including intensive livestock buildings, will require planning permission regardless of size. Another point that has been put to us is that under Article 4 of the General Development Order, a local planning authority may, with the approval of the Secretary of State for the Environment, direct that permission is required for a particular development or class of development that would normally qualify for exemption, so that means already exist to impose tighter control in particular areas where experience shows this to be necessary. The point has also been made that even where a building is exempt from planning control it is still subject to control by local authorities through the Building Regulations (made under the Public Health Acts 1936 and 1961) and that if pollution should subsequently occur it can be adequately controlled under existing public health and water pollution legislation. With regard to control exercised under the Building Regulations, however, we think that while this will cover some aspects of design and construction, including drainage, that are relevant to pollution risks, it will not ensure that all pollution considerations are taken into account; it does not, for example, cover the basic question of siting.

7.9. In contrast, the general view of those bodies concerned with pollution control is that there is need to strengthen planning control on agricultural development. In particular, there is concern by water authorities (in Scotland, the river purification boards) that developments such as intensive livestock rearing, slurry handling facilities, drainage improvement schemes or silage making may proceed, even with grant aid from the Agricultural Departments, without adequate consideration of potential pollution risks. The authorities consider that pollution incidents occur that could have been avoided if the authorities had been consulted beforehand about the development. The question of consultation is closely linked with the planning issue and we return to it below.

7.10. Others have considered the question of agricultural developments in relation to planning control. We note in particular that Mr. George Dobry, QC, in his "Review of the Development Control System" (1975)([100]), commented that "the pattern of agriculture is changing" and that "farming is now an industry", and recommended that Class VI should be amended to exclude:

(*a*) buildings within 100 metres of existing buildings; and

(*b*) intensive building groups [which], although for the use of livestock, are not requisite for the use of land for agriculture.

We take it that the intention of *(b)* above is that all buildings to be used for the intensive rearing of livestock should be subject to control.

7.11. This is certainly the view that we have formed. We are clear that in terms of polluting potential, intensive livestock units must generally be seen as industrial in character and that, from the pollution viewpoint, they should be subject to controls similar to those applied to other forms of industry. Whether an intensive livestock unit development is subject to planning control should be dependent not upon the size of the building but upon the use. We have in mind here not only new units (where we accept that most are likely to be of such a size as already to require planning permission) but the extension of existing units or the conversion of an existing building to form an intensive livestock unit. One approach on this latter point would be to establish intensive livestock units as a special use class under the Town and Country Planning (Use Classes) Order 1972. We do not think that the case for this extension of control is lessened by the possibility of action to deal with odour nuisance or water pollution under the public health or water pollution legislation. Such action is after the event. In our view, the potential pollution problems associated with intensive livestock units are such that it is in the interests of farmers no less than the public that these problems should be considered before a development proceeds, rather than be discovered by experience and perhaps require expensive changes for their correction. Nor do we think that the possibility of removing exemption through Article 4 directions constitutes a generally appropriate remedy. This action is applicable in situations where a development that would normally be acceptable may be undesirable in a particular area because of special local circumstances. It is not an effective means of achieving the general control that we believe to be desirable.

7.12. We therefore recommend that Class VI should be amended to exclude intensive livestock units. We see no need for the exclusion to be related to the question of whether the units are, or are not, "requisite for the use of land for agriculture". The risks of pollution are not directly related to the amount of livestock feedstuff produced on the holding; the concern is, so to speak, with output rather than input. It might be argued that a holding producing a large proportion of the feedstuff would necessarily be of sufficient area to ensure that the unit could be sited, and the manure or slurry disposed of, without causing pollution. The choice of site and of methods for handling and disposing of slurry could, however, still be significant in reducing pollution risks. We think, therefore, that planning approval should be required irrespective of the size of the holding; the industrial nature of an intensive livestock unit is not affected by the amount of land on which it stands.

7.13. We recognise that the amendment we have proposed to Class VI of the General Development Order will call for a definition of an intensive livestock unit. The framing of an acceptable definition will involve many detailed factors and we have not attempted it ourselves. The pollution risks that concern us are associated mainly with intensive units housing pigs or poultry, rather than with dairy herds or beef cattle which are housed during winter months, and we would expect this to be reflected in the definition. The aim should be a definition based on consideration of the polluting potential of intensive livestock units. We recommend that this should be undertaken by MAFF and DOE with the other Departments concerned.

7.14. It is of interest to note here that in the EEC Commission's proposals for a Directive on environmental impact assessment, intensive livestock farming constitutes one of the classes of development projects for which it is envisaged that such an assessment might be prepared. We would agree that the environmental effects of very large-scale developments in this category could be such as to justify the application of this technique.

7.15. We have noted that there is some uncertainty about whether freshwater fish farming comes within the scope of planning controls. We were informed, however, that the Scottish Development Department had advised Scottish planning authorities that fish farming should be subject to control. The position in England and Wales is under review by DOE and MAFF in the light of concern expressed by the NWC to which we referred in paragraph 2.30. We see fish farming as another aspect of intensive livestock farming and we recommend that in view of the rapid growth of the industry and the pollution risks we have described, it should be subject to planning control. We also endorse proposals that have been made by the NWC that the present exemption of fish farming from the normal abstraction control system should be removed and that a system of registration of such farms should be introduced.

7.16. Beyond the changes we have proposed above in respect of intensive livestock units and fish farms, we see no present need, from the pollution viewpoint, for amendment to the class of agricultural exemptions described in the General Development Order. Pollution may be caused by other agricultural developments that are exempt under Class VI, for example, the construction of silage clamps, but we do not think that the problems are of such a nature as to call for planning control. However, whether or not a development is subject to planning control it is important that the possible pollution consequences should be considered and we are not satisfied that sufficient thought is generally given to this aspect at present. One issue that arises is the need for consultation with the authorities concerned with pollution control about the effects of new developments. We consider this point in relation to developments that are subject to planning control in paragraphs 7.19–7.22; in paragraphs 7.47–7.50 we consider the need for consultation in respect of grant-aided developments.

Wider aspects of planning and agriculture

7.17. In the above paragraphs we have been concerned with the control of intensive livestock unit developments from the pollution viewpoint. Development control is, however, only one aspect of planning: it should be seen in the context of development planning for an area. The relationship between planning and pollution was considered by the Commission in its Fifth Report([80]) which dealt with the arrangements for the control of air pollution. The Commission commented (paragraph 335) that pollution is "often dealt with inadequately, and sometimes forgotten altogether, in the planning process" and stressed the importance of ensuring that pollution considerations are taken into account in both strategic planning and in the assessment of proposals for individual developments. We strongly endorse this view. In relation to agriculture and intensive livestock units, the responsible Departments should ensure that there is positive planning for areas where development is likely to be concentrated; the initiative of the Humberside County Council to which we refer in paragraph 7.24 provides an example of this.

7.18. More generally, there is a need for planning to take account of agricultural activities in those areas where conflicts between settlements and agriculture are most concentrated, that is, in the urban fringe. It is in these areas that the effects of agriculture on the public (in particular, smell problems) are likely to be most troublesome and where the impact of urban and industrial pollution on agriculture is likely to be most severe. In these areas, too, agriculture is more prone to damage resulting from recreational activities, trespass and vandalism, problems to which we referred briefly in the previous chapter and which are exacerbated by urban sprawl. It is not the purpose of our study to examine these issues, although we have noted sympathetically the views expressed by other bodies, in particular by the ACAH in its report "Agriculture and the Countryside"([9]). From the evidence we have received, however, we have formed the view that insufficient official attention has been given to questions of land use in the urban fringe and the pollution problems that can ensue. We therefore welcome the initiative being taken by the Countryside Commission with MAFF and DOE to set up an experiment to examine these problems and to test solutions to them.

Consultation by planning authorities

7.19. The Commission also discussed in its Fifth Report the need for consultation by planning authorities with relevant bodies concerned with pollution in their assessment of the pollution aspects of development policies and proposals. The Commission urged that planning authorities should consult pollution control authorities about relevant developments, and noted that consultation was often inadequate even between planning and environmental health departments within the same local authority. The Commission considered whether consultation should be made mandatory; it reached the view that it would be difficult, and probably wrong in principle, to do this with respect to local authorities where both planning and pollution are the responsibility of the same body. On this aspect the Commission recommended that local authorities should ensure that their environmental health departments are consulted on all relevant applications and that their views are given due weight. The Commission concluded, however, that consultation should be mandatory with the Alkali Inspectorate (or with the new inspectorate which, as recommended in the Commission's report, would succeed the Alkali Inspectorate) if the development involves a "scheduled" works, when that Inspectorate is the body responsible for controlling emissions.

7.20. The Commission is still awaiting the Government's response to the recommendations of its Fifth Report. We note, however, that similar considerations arise in the context of agricultural developments. We are here concerned primarily with two aspects of pollution; smell problems and pollution of water. The first of these is the concern of Environmental Health Officers and on this aspect we go further than our predecessors: we recommend that consultation by planning authorities with the environmental health authorities should be mandatory. Our view on this point was strengthened by evidence we received from the Environmental Health Officers' Association which included a recommendation to this effect. On the second aspect, we recommend that it should be mandatory for planning authorities to consult water authorities on development proposals which may have significant water pollution implications. We think that this should cover all intensive livestock unit developments. We recommend that DOE, the Welsh Office and MAFF, in consultation with water authorities, should consider whether mandatory consultation should apply to other classes of development; the corresponding bodies should similarly consider arrangements in Scotland and Northern Ireland.

7.21. These arrangements would provide for consultation with bodies whose interests may be affected by pollution arising from intensive livestock unit developments. We think that planning decisions in respect of such developments should also reflect specialist advice on the polluting potential of these units and on the means available to reduce pollution risks. We consider that MAFF (ADAS) staff are in the best position to provide this advice. At present, it is not mandatory for planning authorities to consult MAFF on individual applications for agricultural development that require planning consent; when requested, the Minister provides an appraisal of the agricultural considerations relevant to a proposal and a judgement on the effect on a holding of a refusal to allow a development. We recommend that for intensive livestock unit developments it should be mandatory for planning authorities to consult appropriate expertise within MAFF on pollution aspects. We comment further in paragraph 7.42 on the arrangements that should be made to establish this source of expertise.

7.22. Finally, in this section, we note that consultation by planning authorities with the appropriate bodies concerned with pollution is desirable where pollution from urban or industrial development may adversely affect agriculture. The effects on agriculture of emissions from proposed industrial development should be assessed. These effects are likely to be of most concern where "scheduled" industries are involved and, as mentioned above, the Commission recommended in its Fifth Report that it should be mandatory on planning authorities to consult the Alkali Inspectorate (or its successor) about the pollution consequences of such developments. There should be consultation with Environmental Health Officers and with MAFF (ADAS) where new residential development is proposed close to an existing intensive livestock unit. ADAS would be able to advise on whether the pollution control arrangements in use by the unit were capable of being improved, should that be deemed necessary in order to avoid a potential problem of smell nuisance.

Planning guidelines in relation to intensive livestock unit developments

7.23. The view expressed to us by agricultural bodies is that, generally, applications for intensive livestock unit developments should be judged on normal planning criteria; it is held that the reduction of pollution to a practicable minimum will be achieved where the principles of good husbandry are observed and that where pollution results from bad practice, it can be dealt with adequately under existing public health or pollution control legislation. As indicated in paragraph 7.11, we would not accept this view. We think that the risks of pollution from intensive livestock units are sufficient to justify constraints on their development and operation which are more specific than those that could be assumed to operate through the use of good agricultural practice.

7.24. The need to set such constraints has evidently been felt by planning authorities in the Humberside region, where there is an unusually high concentration of intensive livestock units. The district councils concerned recognised that there would be advantages in adopting a consistent approach to the problems posed by such developments and agreed to the preparation by the Humberside County Council, for inclusion in its structure plan for the county, of a subject plan* for intensive livestock units. The subject plan sets out proposed policies for intensive livestock unit developments and incorporates criteria designed to protect amenity and (in association with the guidelines prepared by the Yorkshire Water Authority to which we refer further below) to safeguard water supplies. Thus, the plan includes criteria for minimum distances between new intensive units and existing or proposed housing; for the areas of land that should be available for spreading slurry and for minimum distances between such areas and housing; for the rates of slurry application; and for storage requirements for slurry so as to avoid the need to spread under unsuitable conditions. The criteria relating to land requirements for slurry spreading reflect advice on the avoidance of pollution from this activity that is already issued by MAFF in its advisory material. We understand that after further consideration of the matter by a panel appointed by the Secretary of State for the Environment, it has been decided that a subject plan is not the proper medium for handling the problem of intensive units and that the local authorities have agreed that the policy to be adopted on this matter should be separately developed. Whatever the form in which it is promulgated, we would stress our view that a consistent policy should be applied within the area as a whole, rather than that differing policies should be developed by individual districts; we would expect this policy to be based on the central guidance to which we refer in paragraph 7.29.

7.25. Concern with the risks of pollution of water supplies from intensive unit developments led the Yorkshire Water Authority to prepare guidelines for the storage and disposal of animal wastes from these units. The Authority's initiative paralleled that of the Humberside County Council; indeed, the two bodies appointed a Joint Working Party to advise them. The guidelines incorporate criteria relating to the construction and capacity of slurry storage and to practices for the disposal of slurry to land (including a limit on the maximum amount of slurry to be disposed of per hectare per year), with special criteria designed to protect groundwater where slurry is stored or spread in areas of exposed aquifers. In order to protect boreholes used for public supply, a "screening zone" is proposed around each borehole within which slurry should not be stored or spread without prior clearance by the Authority. Similar screening zones are proposed upstream of abstraction points from surface waters.

7.26. MAFF regional staff and the local NFU Branch co-operated with the Yorkshire Water Authority in the preparation of the guidelines. The guidelines have apparently been accepted for application in the particular area of North Humberside, notwithstanding doubts that were expressed to us by MAFF

*Structure plans are prepared by county planning authorities and set out strategic policies and general proposals for the development and other use of land in their areas. These plans require approval by the responsible Minister. More detailed local plans, normally prepared by district councils, must conform with the structure plans. They may include subject plans which are intended to set out in detail policies and proposals for particular areas of planning, for example, mineral extraction or the route of a motorway.

about whether the proposed maximum limit for slurry application, and the proposed consultation arrangements with respect to screening zones, constitute appropriate methods of preventing pollution. We were informed that while the NFU accepted the guidelines in the special circumstances of North Humberside, it did not accept that they would necessarily be appropriate in other areas; and that the Union was preparing a "model" set of guidelines for the development of intensive livestock units and the disposal of effluent which could be adopted by any authority wishing to introduce them. The guidelines have recently been published and we welcome this NFU initiative. However, while they provide useful general guidance relating to the avoidance of pollution, we do not think that the guidelines provide the specific criteria that may be needed for planning purposes.

7.27. Agricultural bodies are generally opposed to constraints of the kind envisaged in the Humberside County Council plan; for example, the proposed limitations on the siting of units or the spreading of slurry within specified distances of housing. The NFU commented, for example, that such limitations would bear arbitrarily on farmers who happen to farm close to residential areas and could well impose unjustified restrictions on the development of their businesses. MAFF expressed the view that such a "cordon sanitaire" could well lead to inflexibility and a waste of resources without necessarily providing a guarantee that pollution would not occur. The Ministry pointed out, also, that the desirable separation between slurry spreading operations and nearby housing would be affected by the technique employed.

7.28. We are not persuaded by these arguments. We think it should be possible to formulate guidelines embodying reasonably precise criteria which would not bear unduly harshly on farmers and which would go far towards avoiding problems of smell nuisance or water pollution. We have in mind criteria of the kind embodied in the proposed Humberside County Council subject plan and the Yorkshire Water Authority guidelines, relating to the desirable separation of intensive livestock unit developments or of slurry spreading from housing, to the amounts of slurry or manure applied to land, to the circumstances of such applications (including the weather, soil conditions and the mode of application), and to slurry storage arrangements and capacity. We do not envisage that the guidelines would be rigidly applied; they would need to be interpreted in the light of particular local circumstances.

7.29. We note here that conditions of the kind discussed above are already applied in several other European countries. In France and in the Federal Republic of Germany, for example, limits are set or recommended on the amount of slurry that may be applied to the land and on minimum distances between land used for spreading and dwellings or between intensive livestock units and dwellings. On this point, MAFF commented that in general the European nations tended to favour "more inflexible" arrangements. We are doubtful about the "flexibility" argument; it may too readily be adduced, as we believe it is here, to justify the existing system on the basis of a vague, general principle without considered analysis of the pollution implications.

Though we commend the action taken by the Humberside local authorities and the Yorkshire Water Authority in attempting to meet the problems posed by intensive livestock units, we think that the initiative in this matter should be taken by MAFF. We consider that there should be central guidance to planning authorities, embodying model criteria relating to the reduction of pollution risks from these units, and that it is properly the responsibility of MAFF, in consultation with DOE and other bodies concerned, to provide it. We recommend that MAFF should undertake this work.

Pollution control in relation to intensive livestock units

The use of planning conditions

7.30. We have discussed the question of criteria which should be applied to the development of intensive livestock units with the aim of reducing the risks of pollution. Some criteria, for example, those pertaining to the separation between intensive units and housing, or the areas of land available for slurry spreading, relate to requirements which would need to be met before planning permission was granted. Others, such as criteria that would seek to limit the rate of slurry disposal to land or the numbers of livestock, relate to the farming practices that would subsequently be employed. As we have indicated, we regard intensive livestock units as industrial in character and we consider it reasonable to require the observance of operational practices designed to reduce pollution risks. One approach to this that has been adopted by some planning authorities is to attach conditions to planning consents which relate to the operation of these units. We were informed that this practice appears to be increasing in some parts of the country. In objecting to this practice, some agricultural bodies have expressed the view that it is wrong in principle for planning authorities to seek to control pollution through the imposition of planning conditions and, in support of this proposition, have referred to views expressed on the matter in the Commission's Fifth Report([80]).

7.31. In that report the Commission was concerned with the use of conditions designed to control air pollution from industrial development, especially for registered works coming under the control of the Alkali Inspectorate. The Commission considered that it was wrong in principle for planning authorities to seek to control pollution by use of the planning laws where separate legislation exists for that purpose; and that the practice was likely to lead to confusion and also to be counter-productive in that conditions specified rigidly at the outset could undermine the pollution control authority's work in seeking progressive improvements in pollution abatement.

7.32. The Commission's views on this point must, however, be seen against its recommendations as a whole. The Commission did not argue that conditions relating to pollution control should not be imposed on new developments but that these conditions should be determined under pollution control legislation rather than rigidly embodied in planning consents. Powers to set such conditions are available under existing legislation for registered works where responsibility for control rests with the Alkali Inspectorate but not generally for non-registered works where local authorities can take action under the public health legislation only after a nuisance has occurred. The Commission envisaged that new, comprehensive legislation should be introduced, providing the same basis for control for all industrial discharges to air. We return to the question of legislation below but here simply note that the views expressed in the Commission's Fifth Report imply no acceptance of the proposition that it would be wrong to set constraints on intensive livestock developments from the pollution viewpoint, or even that it would be wrong in principle to do so through planning conditions when no alternative means exists under pollution control legislation.

7.33. We believe that where development control is needed on pollution grounds it is understandable and proper that planning authorities should wish to obtain assurances, as a condition of consent, that the operating practices adopted will be such as to reduce pollution risks to an acceptable level. We think, therefore, that the question of whether planning conditions should be used to control pollution cannot be answered in isolation. It is necessary to consider the other means that are available to ensure that good practices are observed from the pollution viewpoint.

Control arrangements

7.34. The control of pollution arising from agricultural activities is exercised by local and water authorities under the relevant public health or pollution control legislation. Where regular discharges to water courses occur which require water authority approval, these authorities will take pollution considerations into account in setting their consent conditions. The authorities can take action against accidental pollution after it has occurred. A similar position obtains with regard to the smell nuisance posed by intensive livestock units. A local authority (or a private citizen) may take action under the Public Health Act 1936 to seek the abatement of an existing nuisance. Under the Public Health (Recurring Nuisances) Act 1969, an authority can take action against an expected nuisance if the nuisance has occurred in the same premises in the past. There is, however, no provision for local authorities to take preventive action before a nuisance occurs, or to impose conditions from the outset on the activity that may cause a nuisance. We think that the present degree of control is generally insufficient for intensive livestock units; we have in mind particularly the problems that arise from the spreading of slurry and the fact that these problems are likely to increase given the expected trend towards larger units. We have reached the conclusion that there is a need for some overview of operational practices and for more direct control over what is done. Various approaches can be taken to this question, as we describe in the following paragraphs.

7.35. Since we regard intensive livestock units as industrial rather than agricultural, it could be argued that they should be subject to the same constraints as other industrial enterprises. On this basis, the disposal of animal waste on land would be subject to Part I of the Control of Pollution Act 1974, although clearly the site-licensing provisions of the Act would require to be adapted for this purpose. It could be envisaged that licences would be issued for the disposal of slurry on designated areas and at specified rates. At first sight, this approach would appear to imply a quite unwarrantable degree of bureaucratic control, out of all proportion to the extent of the pollution risks posed by the spreading of slurry. We do not think that this need be so; for example, it could be arranged that after the first licence had been issued, renewal would be automatic unless a failure to observe the terms of the licence had resulted in complaint about pollution. Nevertheless, for several reasons we do not favour this approach if a better way can be found. It would apply control generally, whereas the need is rather for the ability to exercise greater control in particular areas where problems are most likely to arise. It would also call for agricultural experience within waste disposal authorities which these authorities could not generally be expected to possess.

7.36. Another way of securing greater control would be to class the operation of an intensive livestock unit as an offensive trade. An activity may be placed in the category of "offensive trade" either by statute (that is, by virtue of its inclusion in Section 107(1)(a) of the Public Health Act 1936) or by order made by a local authority and confirmed by the Secretary of State for the Environment. Offensive trades are largely concerned with the processing of animal products; examples are the trades of blood boiler, glue maker, gut scraper, maggot breeder, fish frier, knacker, offal boiler and swill boiler. These trades create smells that are likely to be more offensive and more persistent than those caused by livestock units. Offensive trades are subject to special control: they may be carried on only with the local authority's consent, which can be given for a limited period; and the manner in which they are carried on may be controlled by bye-laws made by the local authority and confirmed by the Secretary of State. While we do not think that classification as an offensive trade would be the best way of dealing with intensive livestock units, we note that it would have the advantage of providing a flexible basis for control.

7.37. The operation of the law relating to statutory nuisance is at present under review by the DOE. We noted above that there is no provision within the existing legislation for authorities to take preventive action before nuisance occurs and this is one of the factors that is being considered in the review. It is possible that there will be agreement on the provision of a power to take anticipatory action against statutory nuisance. Such a power might be on the lines of that provided under Section 58 of the Control of Pollution Act 1974; the section deals with noise and empowers a local authority to take action not only where a noise nuisance exists but where it is likely to occur. Generally, we would be in favour of a provision of this kind. In relation to nuisance caused by intensive livestock units, we envisage that a local authority could take anticipatory action of this kind where there was evidence that the guidelines we have referred to earlier were not being observed.

7.38. Yet another approach is suggested by the recommendations made in the Commission's Fifth Report[80]. We have observed that in that report the

Commission proposed that powers similar to those of the Alkali Inspectorate should be available to local authorities for the control of emissions from unscheduled processes; in particular, local authorities should have powers of prior approval of pollution control equipment and powers to require the use of the "best practicable means" to abate pollution. We recognise that while the "best practicable means" concept is reasonably well defined and understood in relation to emissions from a works (which can be monitored and measured) there could be considerable difficulties in applying it to the smell nuisance that might arise from intensive livestock units and from slurry spreading. We think, however, that extension of the concept should not present insuperable problems. In principle, there would seem to be no reason why requirements relating to the operation of a unit, the areas used for slurry disposal and the conditions in which slurry disposal is undertaken, should not be embodied in a statement of "best practicable means" for that unit. The setting of these requirements could be seen as a process of defining good agricultural practice more precisely to take account of particular local circumstances and to achieve the desirable balance between the interests of the industry, the public and the environment.

7.39. Finally, we have considered another possibility which is closely related to the one discussed above; that is, whether controls of the kind exercised by the Alkali Inspectorate should be applied, in the agricultural field, by a new inspectorate. Such an inspectorate should, by definition, be experienced in agricultural matters and it appeared to us that it might most appropriately be formed within the ADAS organisation. Our discussions with MAFF evinced no reasons why this could not be done. The Ministry was concerned that an inspectoral role might prejudice the position of ADAS advisory officers as the "farmers' friend" and considered that if a case for such inspecting powers could be made they might best be exercised by a separate inspectorate within ADAS. An alternative, which we have not explored in detail, is that these powers should be exercised by the existing agricultural inspectorate within the Health and Safety Executive (HSE). This inspectorate, which was formerly part of MAFF and which was transferred to the HSE in 1976, is concerned with the health and safety of agricultural workers and of other people who might be directly affected by agricultural activities. We do not consider, however, that the HSE inspectorate would be an appropriate body to take action against practices which might, for example, cause pollution of water supplies, or create nuisance problems due to smells (which could not be seen as a health risk), or harm wildlife.

Recommendations on control arrangements

7.40. In considering these various possibilities we have had several general requirements in mind. Firstly, there is a need for some monitoring of the operation of intensive livestock units to ensure that the practices adopted are satisfactory from the pollution viewpoint. Secondly, for new intensive livestock unit developments (including extensions to existing units), pollution aspects should be formulated with the aim of reducing pollution risks to an acceptable level; this would be a matter of interpreting the central guidelines in the light of local circumstances. Thirdly, a more ready means is required than is provided under existing legislation for taking action against practices that are likely to cause nuisance problems. Fourthly, we should not wish to add, without very good reason, to the number of official bodies with which farmers have to deal. We think that the pollution risks associated with intensive livestock units are significant and that action is required to deal with them but that this should be done, as far as possible, by extension of existing arrangements rather than by radically new methods.

7.41. We have concluded that, for the present at least, the case for a new inspectorate with powers similar to those of the Alkali Inspectorate is not sufficiently strong. The question then arises how the monitoring requirement referred to above is to be met. We do not think that Environmental Health Officers, who have already a very wide range of duties, could be expected to undertake the kind of regular supervision that we think is needed. We have in mind that appropriate officials, on regular visits to intensive livestock units, should check the operational arrangements from the pollution viewpoint. They should check, for example, that arrangements for the storage and handling of slurry are adequate; that arrangements for the disposal of dead animals (especially poultry) are adequate; and that operational requirements that may have been set for the units to reduce pollution risks are being observed.

7.42. Such a role could not readily be added to that of ADAS advisory officers. The inspecting nature of the duties might tend to undermine their relationship with farmers; moreover, these officers can visit farms only when invited. We think, however, that it should be possible to provide for this pollution inspection function by an extension of the duties exercised by existing specialists within MAFF. We have not examined this matter in detail but one possibility that occurs to us, and which we mention by way of example, is that this responsibility might be assigned to the existing Veterinary Service. We understand that veterinary inspectors visit intensive livestock units regularly and have access as of right. We think that the inspectors could readily acquire the necessary competence and that the additional duties would not be onerous or add significantly to staffing requirements. To whichever group these duties may be assigned, we no not envisage that in this pollution role the inspectors would have enforcement powers; they would provide guidance to the farmers and, where they considered such action to be necessary, they would alert water authorities or Environmental Health Officers to malpractices which appeared likely to lead to avoidable pollution problems. The inspectors would quickly acquire an expertise which would be relevant and of value to planning decisions. It is this body of expertise that we had in mind in making our recommendations (see paragraph 7.21) that it should be mandatory on planning authorities to consult MAFF on proposals for intensive livestock unit developments. Corresponding arrangements should be introduced in Scotland and Northern Ireland.

7.43. This inspecting function should be linked with powers for anticipatory action by local authorities; these powers might be provided through either of the approaches described in paragraphs 7.37 and 7.38. We envisage that Environmental Health Officers, in consultation with the inspectors, would determine the conditions that should be imposed on the operation of intensive livestock units from the pollution viewpoint; they would jointly, in effect, determine the "best practicable means" for the units. Where nuisance problems appeared likely to occur because of a failure to observe the agreed conditions, the local authority could take action under anticipatory powers. The setting of preconditions would apply to new units or extensions but might not be applicable to existing units. We think, however, that the adoption of this approach for new developments would gradually create a climate in which the problems associated with some existing intensive livestock units might more readily be solved.

7.44. Given arrangements of this kind, whereby operational conditions are separately specified in advance with powers for subsequent enforcement, we would see no case for embodying these conditions in planning consents for new intensive livestock unit developments. This would introduce undesirable and unnecessary rigidity; we think that there should be scope for changing the conditions, by agreement, to take account of developments in operational techniques which might significantly reduce the risk of nuisance problems.

7.45. The anticipatory powers for local authorities which we have assumed above are not available at present. There appears to be a good prospect that they will be provided as a result of the current review of the law relating to statutory nuisance but this cannot be regarded as certain. We have therefore considered the situation on the assumption that these powers are not provided. In those circumstances we would still see a role for inspecting agencies of the Agricultural Departments in seeking to ensure the adoption of good operating practices in intensive livestock units. We do not suppose, however, that this would, of itself, satisfy local authorities regarding the control of nuisance from these units. We see a need to set constraints on operating practices, in advance, where nuisance problems may be caused; while we are agreed that the imposition of planning conditions is an inappropriate method for seeking to control the day-to-day management of an enterprise, the practice appears logical and defensible where no other means of achieving this aim are available. This is not to say that the practice is legitimate or effective; we are not aware that the validity of such conditions has been tested or that they could be enforced. Nevertheless, we would suppose that the attachment of conditions to planning consents would increase the likelihood that they will be observed.

7.46. We have considerable doubts about whether a system involving local authorities acting under present legislation (that is, without anticipatory powers) together with an inspecting agency in the role we have described, would provide a sufficient degree of control, whether or not conditions are set in planning consents. For such a system to work satisfactorily, there would need to be a substantially increased commitment by MAFF to the preparation and promotion of model conditions for the operation of intensive livestock units and to the work of the type of inspectorate discussed in paragraph 7.42 in seeking to ensure that these conditions are observed in practice. If this commitment were not forthcoming, and in the absence of the anticipatory powers for local authorities on which our preferred solution depends, then we would consider that other alternatives that we have outlined above would need to be adopted: that is, the disposal of excreta from intensive livestock units should be subject to control on the basis of Part 1 of the Control of Pollution Act; or a greater measure of control should be achieved by classifying intensive livestock unit operation as an offensive trade.

Consultation in relation to grant aided developments

7.47. As described in paragraph 5.35, there are two grant aid schemes under which grant aid may be awarded for farm developments. The water authorities expressed dissatisfaction with the present system under which farm developments that may have water pollution implications could proceed with grant aid but without consultation with these authorities. Cases have been mentioned to us where farmers have been prosecuted who stated in court that they had constructed slurry handling facilities in accordance with MAFF advice and with grant aid, and where the water authority concerned believed that the pollution incidents that occurred could have been avoided if there had been prior consultation about drainage arrangements.

7.48. Generally it appears that there is good liaison between MAFF, principally ADAS, and water authorities, both formally though such bodies as the regional Farm Waste Committees (some of which have water authority representation) and through informal contacts between technical and scientific staffs. The Minister is responsible for appointing members of each water authority to represent the interests of agriculture, land drainage and fisheries. Similar arrangements exist in Scotland. This co-operation does not necessarily extend, however, to individual grant aided developments. We were informed by MAFF that the Ministry (ADAS) officers who deal with applications for grant aid are instructed to advise applicants to consult water, local and any other relevant authorities who might be concerned with the proposals. It is not, however, a condition of grant award that such consultation should be undertaken. An applicant is reminded that it is his responsibility to obtain any necessary wayleaves, easements or consents in connection with the proposal and he is required to indicate that this has been done; we understand, however, that all that is called for is a "tick in the box" on the grant application form.

7.49. Somewhat different and, in our view, preferable, arrangements exist in Scotland where an applicant for grant aid is required by DAFS to submit a certificate from the water authority confirming that the authority has been consulted by the farmer about the proposed development. This requirement applies for any development which could have water pollution implications, whether or not the development involves a discharge which would require a formal consent by the water authority. We were informed that this difference in the procedures followed in England and Scotland is currently being considered within MAFF and DAFS.

7.50. The view that consultation with water authorities about grant aided farm development schemes should be compulsory is generally opposed by agricultural bodies. The question of the confidentiality of the relationship between the farmer and ADAS officers appears to lie at the root of this opposition. We were informed that this confidentiality rests on the Official Secrets Act, 1911 and we were pleased to learn that the matter is now being considered within MAFF. It has been put to us that a farmer seeking grant would have to divulge information to ADAS about the management and finances of his business which he would not wish to go to a third party. We can readily see that some information required by ADAS in assessing grant applications may be confidential in nature but we do not accept that this need be a barrier to consultation with water authorities about those practical aspects of development proposals that may affect their interests. We think that a farmer who is seeking a grant from public funds should be prepared to take all reasonable steps to ensure that the development for which the grant is required is unlikely to affect adversely some other public amenity. We accordingly recommend that it should be a condition of grant aid for developments that could cause water pollution to submit evidence that the relevant water authority has been consulted and that its views have been taken into account in the proposals. As noted above, this is to recommend the adoption throughout the UK of the practice in Scotland. We note here that if a development for which grant aid is claimed is of a kind that requires planning permission then, under the recommendation we have made above, there would be consultation with the water authority at this stage. We have not considered the administrative procedures involved but clearly these should be devised so as to avoid any overlap in the requirement for consultation.

7.51. A similar requirement for consultation arises in respect of some other bodies whose interests may be affected by farm developments in particular areas; for example, where a development is proposed on a site that is of special importance from the viewpoint of nature conservation, that is, on a national or other nature reserve or on a Site of Special Scientific Interest (SSSI). We understand that satisfactory machinery exists for consultation with the NCC, and also with the National Parks Authority in respect of proposed developments within a national park. It is another matter, but one that is not within our remit, whether such consultation achieves an appropriate balance between the needs of agriculture and of conservation; the NCC commented in its report "Nature Conservation and Agriculture" that MAFF and DAFS may give grants for agricultural improvements on SSSIs which damage or destroy those features for which the sites were scheduled.

7.52. If an application for grant aid is rejected on environmental grounds (see next paragraph), representations may be made to the appropriate Regional Panel. These Panels are non-statutory, advisory bodies which are appointed, in the English regions, by the Minister of Agriculture, Fisheries and Food (in Wales and Scotland, by the appropriate Secretary of State). The composition of the Panels reflects all sections of the agricultural industry; the members include farmers, landowners and workers. An informal procedure exists under which the Panels may hear representations against grant decisions and make recommendations to the appropriate Minister. We recommend that the membership of the Panels should be widened to include other countryside interests and that representatives of water authorities, the NCC or the National Parks Authority as appropriate, should be enabled to make representations to the Panels when appeals are being considered. This procedure is already applied in the case of grants for private forestry under the Basis 3 dedication schemes where the Regional Advisory Committees advise the Commissioners in cases where there is an environmental or conservation objection to a planting grant. The composition of the committees was enlarged in 1976 to include representatives of local authorities, farming and conservation.

Farm grant schemes and the environment

7.53. There is no express reference to pollution (or to planning) in the Statutory Instruments that relate to the farm grant schemes. In administering the schemes, however, the appropriate Minister is obliged to conform to Section 11 of the Countryside Act 1968 which provides that, when exercising a function in relation to land, every Minister, government department and public body must have regard to the natural beauty and amenity of the countryside. Ministry officers dealing with grant applications are required to certify that they have conformed to this requirement and it is in exercising this duty that environmental considerations are taken into account. There are provisions in the Statutory Instruments relating to the grant schemes which empower the appropriate Minister, in awarding a grant, to impose such conditions as he thinks fit, and this general provision has been used to impose conditions relating to the reduction of pollution risks. For example, we were informed by the Scottish Office, in relation to silage making, that applicants for grant are required to consult river purification authorities on pollution aspects and to act in accordance with the advice from these authorities.

7.54. The primary purpose of the farm grant schemes is to promote the development of agricultural businesses and we recognise that there is some doubt about how far conditions that relate to considerations of pollution control can properly be attached to grant awards. In the last resort this would be a matter for the Courts to determine. We consider, however, that when considering grant applications, Ministry officers should always take full account of the possibility of pollution in applying the requirements currently imposed under Section 11 of the Countryside Act 1968. The recommendations we have made for improved consultation about the pollution risks associated with developments for which grant aid is sought will, we believe, help to ensure this.

7.55. The arrangements we have so far proposed provide for consultation on pollution aspects in respect of developments that require planning permission and those for which grant aid is sought. Some developments that fall in neither category may have significant pollution implications. Even though a development is eligible for grant aid, a farmer may elect not to seek it. It would seem desirable that consultation to reduce pollution risks should apply generally and not only to those developments for which financial aid is sought. We have considered whether it should be made mandatory on farmers to give prior notification of certain kinds of developments, whether or not these are exempt from planning control, to water authorities, local authority Environmental Health Officers and possibly other bodies as well. Those so informed could be allowed a limited time in which to submit any comments or recommendations. Such consultation would be in the farmer's interests in helping to avoid later pollution problems and the risk of prosecution; and would ensure that the relevant authorities are informed of developments in their areas that might create future difficulties.

7.56. We decided, however, against such a general provision, at least for the present. Most farm developments that may cause difficult pollution problems and for which the pollution risks should be considered from the outset would, we believe, require planning permission or would be the subject of applications for grant aid. We note, however, that circumstances may change: the terms of grant aid might be altered, for example, so that this would no longer provide a vehicle for ensuring the necessary consultation about farm developments. In such circumstances we consider that a more general provision on the lines indicated above would be needed.

CHAPTER VIII

AGRICULTURE AND POLLUTION: A SUMMING UP

Introduction

8.1. The primary aim of our study was to consider the polluting effects of agricultural practices, having in mind the changes that have occurred in these practices over the last few decades and those that may occur over the period up to the end of the century. We undertook the study because we were not satisfied from our preliminary enquiries that sufficient consideration was being given to pollution in relation to agricultural developments. We found a number of assumptions in current thinking: that, in this respect, agriculture is a special and privileged case; that the necessity of food supply takes precedence over environmental requirements and that the observance of good agricultural practices will ensure that any adverse environmental effects are reduced to a practicable and acceptable minimum.

8.2. This view may well be justified for agriculture as it was traditionally practised up to the end of the Second World War. Since that time, as we have described, changes have taken place that greatly increase the impact of agriculture on the environment and which suggest the need for reassessment. The changes that have particularly concerned us in our study are the vastly expanded use of agrochemicals and fertilizers, the trend towards large, intensive livestock units and the related problems of farm waste disposal. We have discussed these aspects in some detail in previous chapters. Here, we first present a brief summing-up of our principal findings; this is followed by a list of our conclusions and recommendations.

Principal findings

Responsibilities for pollution from agricultural activities

8.3. We begin by considering a general issue which we believe to be of prime importance since it underlies most of our more specific findings; that is, the question of where responsibility rests for investigating the polluting effects of agricultural activities. Clearly both agricultural and environmental interests are involved. For simplicity, we discuss this question in the following paragraphs in terms of the relationship between DOE and MAFF but we think that similar considerations arise in respect of the arrangements in Scotland, Wales and Northern Ireland.

8.4. The DOE has several major areas of interest and responsibility in this field. The Department is responsible for considering the standards of environmental quality to be sought in air and water, and for waste disposal and planning. It has, together with the water authorities, responsibility for the protection of water supplies, especially potable water. It is the parent Department for the NCC and the Countryside Commission and is thus concerned with the conservation of wildlife and natural beauty and amenity. The Department has also a broad responsibility, exercised through its Central Directorate on Environmental Pollution, for co-ordinating Government action on the control of pollution.

8.5. The DOE is thus necessarily involved in assessing the effects of pollution on agriculture and those of pollution caused by agricultural activities. However, the Department expressed the view to us, with which we concur, that it would be unrealistic to expect one Department of State to be responsible for all aspects of pollution and that there are strong arguments for requiring environmental protection to be an integral part of good management in all areas of Government activity. It may be noted that this applies to other public bodies; the terms of reference of the National Coal Board and the Central Electricity Generating Board, for example, stipulate that these organisations are responsible for the environmental consequences of their respective activities. It is desirable, therefore, that Departments sponsoring particular industries should take the lead in ensuring that pollution aspects are considered. In some contrast with this viewpoint, MAFF stated that Government policy on environmental pollution (in England) is the responsibility of DOE but that the Ministry participates fully in the formation and execution of policies having an impact in its sector. MAFF commented: "In general, the Ministry's approach is to give all possible assistance towards the overall objective of minimising pollution, while ensuring that the necessary measures are consistent with the Government's objectives for the agricultural industry".

8.6. These two approaches, taken together, suggest to us that there is a gap in the division of responsibilities between the Department and the Ministry for considering the pollution issues raised by agriculture. We commented on one aspect of this gap, in the context of research on nitrate levels in water, in paragraph 4.81. It would appear that in the Ministry's view, the prime initiative for action on pollution rests with DOE. We do not accept this.

8.7. There is a general point we would make here, of considerable importance, and which is by no means confined to agriculture. Over the last decade, great advances have been made in dealing with pollution problems that were a legacy of the past, resulting from developments introduced before concern with environmental issues had become the significant factor in society that it is today. The force of this concern may fluctuate; in times of economic difficulty, for example, society may accept that desirable environmental improvements must be postponed or that "jobs must come first." But the concern is not a passing fashion and it will not disappear. We think it is imperative not to repeat the mistakes of the past. The environmental consequences of new developments and techniques which may find widespread adoption should be fully assessed at the outset. This is not simply a matter protecting the environment; it is vital for protecting the interests of those initiating or using the development. The alternative could be the eventual discovery through experience that a development has unacceptable environmental effects, but at so late a stage that formidable difficulties and hardships may be involved in finding remedies.

8.8. In the agricultural context, we think that the responsibility for promoting the early consideration of the pollution impact of new developments must rest with MAFF, which may well be involved in sponsoring such developments and which is in the best position to assess their probable significance. We therefore recommend that it should be a clear responsibility of the Ministry to take pollution considerations fully into account in its policies. We have referred (see paragraph 7.54) to the general requirements that is placed on Ministers, government departments and public bodies under Section 11 of the Countryside Act 1986 to "have regard to the natural beauty and amenity of the countryside". There should be a similar general duty with regard to pollution; indeed, we regard pollution considerations as an indispensable part of considerations of amenity and we think that Ministers should make clear that the present duty is to be so understood.

8.9. While the main, general responsibility for safeguarding the environment rests with DOE, we think that the initiative for action to deal with pollution caused by agriculture should rest with MAFF. This will imply a new emphasis on pollution matters within MAFF; we have formed the view that the MAFF approach to pollution questions has been unduly defensive and protective towards agricultural interests, although we acknowledge and welcome indications of the Ministry's increasing awareness of the wider issues raised by developments in agriculture, not least in its response to the proposals to which we refer in paragraph 8.26. There is a need to recognise that there may come a point in the continuing striving for higher yields where agricultural advance must give way to environmental considerations.

Pesticides

8.10. It is clear from the evidence we have received that there is much concern about the dependence of modern agriculture on pesticides and about the risks posed by these chemicals to wildlife and, potentially, to man. We accept that the continued use of pesticides is essential to maintain food supplies and that much care is taken by manufacturers, and through the existing control machinery, to ensure safety in use and to minimise adverse environmental effects. We are concerned, nevertheless, about the scale of pesticide use. The official view, and that of the agricultural and agrochemical industries, is that because of the stringent tests to which these chemicals are subjected and the guidance that is given to farmers about their use, the increasing quantities applied give no grounds for anxiety and that the cost of pesticides discourages excessive applications. We take a different view. Pesticides are by design biologically active and hence hazardous chemicals; however stringent the tests applied to them, there is the possibility of unforeseen and unforeseeable effects. They should be used with care, in the minimum quantities needed for effective pest control, and increasing usage should be questioned. The wise use of pesticides is not ensured by the restraining effect of cost.

8.11. We wish, therefore, to see a change in the approach to pesticide use. Such a change would not be superficial, amounting merely to a difference of emphasis which would have little practical effect. We consider, for example, that it could and should have important consequences for the thrust of research and for the allocation of resources to the development of techniques designed to assist farmers in their decisions on pesticide application. Instead of a tacit acceptance of increasing pesticide use, we think it should be the official policy to seek to reduce usage to the minimum consistent with agricultural objectives. Several of our recommendations are intended to further this policy.

8.12. We have made recommendations for changes in control arrangements which would exemplify and foster this different approach to pesticide use. In particular, we recommend that the present separate schemes for assessing the safety and efficacy of pesticides should be amalgamated and that statutory recognition should be given to the combined scheme. We stress the importance of new techniques which offer the prospect of substantial reduction in the amounts of pesticides applied and we recommend increased efforts on the development and assessment of these techniques.We wish to encourage the development of a professional attitude towards pesticide application and, to that end, we recommend the introduction of a licensing system for commercial pesticide operators. We envisage that this system might eventually be extended to farmers and their employees who apply pesticides. We recognise that separate consideration would need to be given to the implications of such a system for the many operators involved in applying pesticides for non-agricultural purposes.

8.13. We believe that tighter controls on pesticide usage are desirable not only on environmental grounds but in the interests of farmers. We are deeply concerned about the threat posed by the development of resistance to insecticides and fungicides and we are not convinced that the significance of this threat has been sufficiently appreciated within MAFF. We recommend that serious attention should be given to the development of strategies to combat pest resistance and to problems that would arise in introducing them.

Fertilizer use: nitrate in water supplies

8.14. We do not doubt that the large increase that has occurred in the use of inorganic nitrogen fertilizer is, directly or indirectly, a major cause of the rising nitrate levels that are observed in many water supply sources. There is concern about these levels because of the risk that nitrate may cause methaemoglobinaemia in infants or that it may be implicated in some forms of human cancer through the formation of N-nitroso compounds, which are known to be powerful carcinogens in a variety of animal species. We have therefore regarded it as an important part of our study to assess these risks, the contribution to them from agricultural practices, and the remedial measures that might be taken should concerted action to reduce nitrate levels appear essential.

8.15. The health risks posed by nitrate in water supplies have attracted much public comment; public concern on the matter has been augmented by the possibility that nitrate levels in groundwater have yet fully to reflect past increases in fertilizer use, so that these levels may continue to rise. We have reached the conclusion, however, that the anxiety that has been engendered about these risks is not justified on the information at present available. Infant methaemoglobinaemia is a rare condition in the UK, even in the few areas where water with nitrate content above the "recommended" level of 50 mg/l (expressed as nitrate) in the WHO European standards has been consistently supplied. With regard to the possible cancer risk, the link with nitrate intake is highly uncertain and we have found no evidence that water containing 100 mg nitrate/l is harmful to adults. We see no basis for departing from the WHO European standards in the UK; that is, we think the 50 mg/l limit is prudent for infants but that 100 mg/l should be taken as the maximum acceptable level for the present. We recommend, however, that further investigation is undertaken to substantiate this maximum acceptable level, particularly in relation to the risk of infant methaemoglobinaemia under UK conditions.

8.16. Although agricultural practice certainly affects nitrate levels in water, the connection between them is complex; in particular, there is much uncertainty about the effect that a reduction in fertilizer use would have in reducing these levels. On the one hand, it appears from the estimates we have received that if action had to be taken to reduce nitrate levels in water (beyond what can be done by water authorities through normal techniques such as the mixing of supplies) it would be more cost-effective for these authorities to install plant for nitrate removal than to impose restrictions on fertilizer use. On the other hand, we stress the need to ensure that fertilizers are used efficiently so as to minimise nitrate losses and the need to assess carefully the effects, in terms of these losses, of new farming techniques which might find wide application.

Farm wastes

8.17. Our main concern under this heading is with pollution risks posed by intensive livestock units. We regard such units as industrial rather than agricultural in character and we consider that insufficient attention has been given to the pollution they may cause. As in other industries, the intensive livestock rearing industry must come to accept the costs of pollution control. We note that treatment systems for slurry from intensive livestock units, which would reduce the smell problems that arise from the storage and spreading of this material, have been adopted to only a negligible extent on farms. We make a number of recommendations designed to further the development and use of these systems. Thus, we recommend that the terms of grant aid schemes should be reviewed to ensure that appropriate provision is made for pollution control; that the MAFF Farm Waste Unit should be strengthened and the adequacy of advisory material on farm waste management be reviewed; and that consideration should be given to whether the present research and development programme on waste management is appropriate in scale and in the division of effort between the various options. More generally, we recommend that official testing arrangements should be introduced to validate manufacturers' claims for plant performance and to provide a means for assessing the environmental effects of new developments.

8.18. We consider that animal wastes should generally be returned to the land but that more attention should be given to achieving a better use of the plant nutrients that these materials contain. We recommend that a study be undertaken of the possible benefits that would derive from a "manure bank" system on the lines of that introduced in the Netherlands.

The effects of pollution on agriculture

8.19. Agriculture is affected in various ways by pollution from urban and industrial sources. We attach particular importance to the risks posed by the application of sewage sludge to land and to the possible effects of air pollution on crops and livestock. On the first matter, there is concern about the effects of heavy metals, other toxic substances and pathogens that may be present in the sludge. We recommend that there should be careful and regular monitoring of the metal content of sludge and of the land to which it is applied. More research is needed to provide a sound basis for policy on sludge disposal; we stress the need for more knowledge on the persistence of pathogens. We consider that, pending such research, it would be wise to assume that the application of untreated sludge to land will be found unacceptable as a widespread practice. On the second matter, we stress that the effect of emissions on agriculture should be carefully assessed in considering proposals for industrial development. We note the potential importance of the effects on crops of relatively low levels of common air pollutants and recommend that the priority accorded to research in this area should be reviewed.

Planning and related matters

8.20. Agriculture enjoys considerable exemptions from planning control and (although we have been urged otherwise) we do not recommend any general change in the present arrangements. We consider, however, that a greater measure of control is needed of intensive livestock unit developments, which may cause substantial environmental problems. We accordingly recommend that exemptions from planning control should be removed so far as intensive livestock unit developments are concerned. We see a need for guidelines to be prepared centrally, dealing with pollution considerations relating to these units, in order to assist planning authorities in assessing proposals. These guidelines would need to be interpreted in the light of local circumstances and we recommend that planning authorities should be required to consult the relevant environmental health authorities, water authorities and also appropriate expertise within the Agricultural Departments (see below) on the pollution implications of proposed intensive livestock unit developments. Such consultation is equally needed where residential development is proposed close to existing intensive livestock units.

8.21. The risk of pollution from intensive units is affected by the operating practices; smell nuisance may be caused, for example, if slurry is spread too close to houses. We consider that for new intensive livestock unit developments, the operating procedures that need to be observed in order to prevent smell nuisance should be identified in advance. Local authorities should have powers to impose conditions requiring the use of agreed procedures and to take preventive action in the event of failure to observe them. We envisage that such powers will be provided as a result of a general review that is being conducted by DOE of the operation of the law of statutory nuisance. We see a need for regular monitoring of the operation of intensive livestock units to check that the practices adopted are satisfactory from the pollution viewpoint and we conclude that this should be undertaken by specialists within the Agricultural Departments who, like the Veterinary Service, would have access as of right to holdings. We consider that the expertise on pollution aspects acquired through this work would be of value to farmers, to planning and environmental health authorities and to water authorities; as indicated above, we recommend that planning authorities should consult this source of expertise on proposals for intensive livestock unit developments.

8.22. Wastes from farms can pollute water courses and it is desirable that farm developments should be planned to reduce the risk of such pollution. We recommend improved arrangements for consultation by farmers with water authorities on developments for which grant aid is to be sought, so as to ensure that water pollution risks are adequately considered. We endorse the need for pollution aspects to be taken into account by ADAS in administering farm grants.

ADAS and pollution matters

8.23. Finally, in this summing up of our principal findings, we comment further on a matter that has been touched on in previous chapters; that is, the role of specialist agricultural advisers in pollution matters. It is again convenient to discuss the question in terms of the arrangements for England and Wales and the role of ADAS. We recognise that the position is different in Scotland where the advisory service is provided through the Scottish Agricultural Colleges; we think, however, that the point we wish to raise is of general relevance and that it should be considered in relation to the arrangements in Scotland and also in Northern Ireland.

8.24. Plainly, as the principal source of professional, scientific and technical expertise in agriculture, ADAS has a crucial role in tackling the problems of pollution arising from agricultural activities. Pollution considerations already affect or determine much of the specialist ADAS work. The "lead" service on pollution within ADAS is the Agricultural Science Service; its regional staff include six disciplines (soil science, microbiology, nutrition chemistry, analytical chemistry, entomology and plant pathology), all of which have specialist responsibilities on pollution. These activities are coordinated technically by several working parties which are wholly or partly concerned with pollution.

8.25. We have proposed a specific extension of the ADAS role in dealing with pollution in our recommendation that specialists within the service should be responsible for checking the operation of intensive livestock units from the pollution viewpoint. Here we are concerned with a more general point. As indicated in paragraph 8.8, we consider that the prime initiative for dealing with pollution from agricultural activities should rest with MAFF. We believe that this would imply an increased emphasis on pollution matters within the Ministry and might call for changes in ADAS organisation.

8.26. Proposals for a wider role for ADAS have been made by other bodies. We referred in paragraph 1.13 to the effects of agriculture on amenity and on wildlife and nature conservation. There has been widespread recognition of these problems, not least within the industry as, for example, in the joint statement on "Caring for the Countryside" prepared by the NFU and the Country Landowners' Association([101]). It was proposed by the Countryside Review Committee([8]) that ADAS officers should advise farmers not only on those matters that pertain to efficient food production but on the environmental considerations that should be taken into account in planning developments in their businesses. A similar proposal was made by the ACAH in its report "Agriculture and the Countryside"([9]). We welcome and support these proposals which we see as one facet of our recommendation regarding MAFF's role in environmental matters; and we welcome the fact that the proposals have been accepted in principle by MAFF. In a similar way, we would expect ADAS officers to be in a position to advise on pollution considerations. We do not doubt that much advice of this kind is already given. Nevertheless, we think that the organisation and functions of ADAS should be reviewed in the light of our various proposals to ensure that pollution aspects are adequately covered and we so recommend.

LIST OF CONCLUSIONS AND RECOMMENDATIONS

8.27. **Changes in agriculture (Chapter II)**

Loss of agricultural land

1. The intensification of agricultural practices that might be necessitated by the loss of agricultural land to urban development by year 2000 is negligible; hence the additional pollution risk that might be posed by such loss is also negligible (2.29).

Organic farming

2. Organic farming offers benefits in pollution terms but is limited in scope; its influence on the pollution issues raised by agriculture generally will remain negligible (2.32).

Long-term studies

3. MAFF should undertake periodic studies of possible long-term developments in agriculture; such studies should find a place in the work of any department of government (2.37).

8.28. **Pesticides (Chapter III)**

Pesticide usage

4. Data on the quantities of active ingredients manufactured and sold should be made freely available (3.10).
5. The principal organisations involved should meet with a view to improving the arrangements for collecting and using data on pesticide usage. MAFF should take the initiative in this matter and the results should be published (3.10).
6. The ACP should keep in close touch with the US Environmental Protection Agency on the possible risks posed by the herbicide 2,4,5–T (3.20).
7. The ACP should review the total (agricultural and industrial) usage of organochlorine pesticides (3.24).

Pesticide resistance

8. Resistance to insecticides and fungicides is a matter of serious concern; strategies should be developed to delay the onset of resistance (3.33).

Aerial spraying of pesticides

9. Advance warning of spraying to occupiers of adjacent land should be mandatory; where this would be impracticable because of the numbers of people involved, aerial spraying should not be used (3.49).
10. The adequacy of present inspection arrangements should be reviewed; consideration should be given to experts from the Agricultural Departments taking part in inspections (3.53).
11. The arrangements for dealing with incidents should be reviewed (3.55).
12. The arrangements for advance notification of aerial spraying should be extended to cover Environmental Health Officers of local authorities and the appropriate regional ADAS office (with corresponding arrangements in Scotland and Northern Ireland) (3.55).
13. The presence of a "groundmarker" during aerial spraying should be mandatory (3.55).
14. Consideration should be given to the introduction of arrangements for the special assessment, through the PSPS, of large-scale aerial spraying operations (3.58).

Policy for pesticide use

15. It should be a declared policy aim to reduce pesticide usage to a minimum consistent with efficient food production (3.75).
16. There should be increased emphasis on ADAS activities designed to improve the basis on which farmers decide their pest control strategies (3.77).
17. An investigation should be undertaken of the effect that present requirements for food quality have on pesticide usage (3.79).
18. Subsection 3(3) of the Food and Drugs Act should be amended with the aim of reducing the pressures on food processors to produce absolutely pest-free products (3.86).

Control arrangements

19. The present schemes for assessing the safety and efficacy of pesticides (PSPS and ACAS) should be combined (3.68).
20. The combined control scheme should be given statutory recognition (3.106).
21. The form and content of the booklet "Approved products for farmers and growers" should be reviewed with the aim of assisting farmers to choose chemicals that will minimise the environmental impact of pesticides (3.69).
22. The relevant organisations should review the extent to which the booklet reaches farmers and growers (3.72); future editions of the booklet should be provided free to farmers on request (3.73).
23. There is need for a more organised approach to the assessment of new techniques for pesticide application (3.96). Arrangements should be introduced for official efficacy testing of such equipment which should also cover environmental considerations (3.97).
24. Considerably greater effort should be applied to the development of ULV/CDA techniques which offer the prospect of substantial reductions in the amounts of active ingredients used; an integrated approach is required involving Government and the industry (3.95).
25. The arrangements concerning confidentiality of data relating to the effects of pesticides should be reviewed; information should not be unnecessarily withheld, especially from those engaged in research in this field (3.108).
26. The role of the Advisory Committee on Pesticides (ACP) should be extended. The ACP should publish periodic reports on its work and should be empowered to advise on research needs in the pesticides field. Consideration should be given to the introduction of a system for reporting on the effects of new pesticides analogous to the "yellow card" system used by doctors (3.109).
27. The DES should review the implications of these proposals for the resources required by the ACP, in consultation with Agricultural and Environmental Departments (3.110).

28. There is need to develop a professional approach to pesticide application. A licensing and training system should be introduced for persons applying pesticides commercially in agriculture. The implications of such a system for operators applying pesticides in non-agricultural sectors would need to be separately considered (3.111).

29. Monitoring surveys should be designed to test the observance of harvest intervals; the use of "spot check" surveys should be considered (3.117).

30. A study should be undertaken with the aim of exposing to public debate the issues involved in the monitoring of pesticide residues and in the contrasting approaches taken on this matter in the UK and other Member States of the European Community (3.120).

Research

31. Greater emphasis should be placed on the development of new techniques to improve the efficiency of pesticide application (3.124).

32. There should be an expansion of basic research on the factors determining the incidence of diseases and pests and on the measurement of economic threshold levels (3.125).

33. Work on the development of strategies to delay the onset of resistance should be strengthened (3.126).

34. There should be a strong commitment to applying the concepts of integrated control (3.128).

8.29. **Nitrate fertilizers (Chapter IV)**

Nitrate and health hazards

35. There appear to be two main concerns: the methaemoglobinaemia that may particularly afflict new-born infants, and a possible link with the aetiology of cancer. As regards the former, infant methaemoglobinaemia is extremely rare in the UK (4.6); with regard to the latter, there is no evidence that unambiguously associates nitrates and N-nitroso compounds in human tissues or body fluids with carcinoma of any organ in man (4.18).

36. The UK should continue to work to the existing WHO European standards for nitrate levels in drinking water (4.66). Investigation should, however, be undertaken to substantiate under UK conditions the maximum acceptable level specified in these standards (4.71).

37. A study should be undertaken to establish the nitrate content of foodstuffs as consumed (4.71).

38. As a basis for epidemiological studies of workers in the fertilizer industry, a rigorous check should be undertaken of the nitrate intake of the workers involved (4.73).

Reduction of nitrate levels in water supplies

39. The evidence suggests that a reduction of nitrate levels in water would be less costly to achieve through nitrate removal by water authorities than by restrictions on agriculture (4.61).

40. It is important in the interests of both farmers and the environment that fertilizers should be used efficiently (4.49). Efforts should be intensified to develop test kits to enable farmers to assess the nutrient requirements of their land (4.52).

41. Research should be undertaken to assess the likely consequences of "maximum yield" methods of cultivation in terms of nitrate losses (4.58).

Research on nitrate levels in water supplies

42. Much research is in progress on the factors that determine nitrate levels in water supplies. It would be timely and useful to prepare a "stock-taking" of this research; this should be undertaken by the DOE/NWC Standing Technical Advisory Committee on Water Quality. The work of the Royal Society Study Group on the Nitrogen Cycle will be of value in this context (4.79). Consideration should be given to the need for more work in a number of areas (4.80).

43. It should be a clear responsibility of the Agricultural Departments to promote research on the polluting effects of agricultural practices, whether or not such work appears likely to bring benefit in terms of farming economics (4.82).

44. There should be more formal links between the fertilizer industry and the ARC; the industry viewpoint should be taken more fully into account in determining the official research programme (4.83).

Eutrophication

45. The need for systematic monitoring of eutrophication trends in still waters should be considered (4.89).

8.30. **Farm wastes (Chapter V)**

Intensive livestock units and animal wastes

46. Intensive livestock units should be regarded as industrial enterprises (5.6).

47. Treatment systems which reduce the smell problems that may be caused by the storage and spreading of animal wastes have been adopted to only a negligible extent on UK farms (5.31). Cost is an important factor; the intensive livestock rearing industry must come to accept the cost of pollution control (5.34).

48. The grant aid systems should be reviewed to ensure that appropriate provision is made for pollution control (5.38). Necessary provision for this purpose should be regarded as an integral part of any development (5.40).

49. Where intensive livestock units are overtaken by urban development and smell problems are thus created, compensation should be payable in respect of waste treatment facilities (5.41).

50. The resources of the MAFF Farm Waste Unit should be strengthened (5.44); the corresponding advisory arrangements in Scotland should be reviewed to ensure that they are satisfactory (5.45). The adequacy of advisory material on waste management should be reviewed (5.52).

51. The programme of research and development on waste management and smell abatement techniques should be reviewed to assess its adequacy and whether the effort is appropriately divided between the various options (5.50). The balance of effort between officially sponsored work and the support of ideas from other sources should also be considered (5.54).

52. Official testing arrangements should be introduced to provide independent assessments of the performance of waste treatment plant (5.55).

53. A study should be conducted of the feasibility of introducing a system similar to the "manure bank" system in the Netherlands as a means of bring about the more efficient use of the nutrient value of animal wastes (5.62).

54. The use of poultry manure as a cattle feed ingredient should be encouraged (5.64).

Straw burning

55. The development and exploitation of other uses for straw should be encouraged. The cost of ploughing-in straw (where this can be done with benefit to the soil) should be weighed against the risks attendant on burning (5.69).

56. Some straw must continue to be burnt in the field (5.70). Careful observance of the NFU code of practice is essential (5.71).

Silage

57. Silage making has been a frequent cause of water pollution incidents (5.76). Pollution from this cause should, however, be a diminishing problem (5.78); improved consultation with water authorities on grant aided developments should help in this (see item 77).

Sheep dipping

58. Arrangements by which water authorities can obtain advance notification of sheep dipping now appear to be operating satisfactorily (5.82).

Disposal of pesticide containers and surplus chemicals

59. Little information is available on the numbers and types of containers involved or the disposal methods adopted (5.83). In view of the

nature of some of the chemicals involved, the adoption of safe disposal arrangements is essential (5.89).

60. Powers should be made available to a competent authority (presumably the waste disposal authority) to require that the disposal procedures set out in the code of practice are observed. The adequacy of the system for distributing the code of practice should be reviewed (5.91).

The storage of chemicals on the farm

61. Current practice for the storage of chemicals on farms should be reviewed (5.95).

8.31. **The effects of pollution on agriculture (Chapter VI)**

The use of sewage sludge on land

62. It is important that a scientific basis for guidelines for the disposal of sludge on agricultural land should be firmly established (6.29). Water authorities should make every effort to adjust their policies to conform to the guidelines (6.31).

63. In view of the problems posed by toxic metals in sludge, there should be greater efforts to reduce contamination of sewage by industrial effluents (6.30).

64. There should be regular monitoring of the levels of toxic elements in sludge and soils to which sludge is to be applied. If possible, water authorities should provide an analysis of maximum metal content and fertilizer value of sludge to the farmers on request (6.31).

65. Research on the extent of survival of pathogens in sludge should be given greater emphasis. Pending the outcome of this work, the practice of spreading untreated sludge should not be extended (6.35).

66. The reasons for an increase in the number of deaths attributed to salmonella infections should be investigated (6.14).

Water supplies for agriculture

67. Pollution of farm water supplies does not constitute a serious problem although continuing care is needed in a number of areas (6.45).

Air pollution and agriculture

68. Research is needed to assess the effects of common aerial pollutants on crop yields (6.60). MAFF should review its support for such work in consultation with other departments and organisations involved (6.67).

Other effects of pollution on agriculture

69. Consideration should be given to the need for review, from the

agricultural viewpoint, of the arrangements for dealing with highway spillages of toxic chemicals (6.68).

70. The provision by local authorities of facilities for rubbish disposal can help to reduce the problems caused to farmers by dumping on agricultural land (6.72).

8.32. **Planning and related matters (Chapter VII)**

Agriculture and development control

71. Class VI of the General Development Order should be amended to exclude intensive livestock units (7.12). A definition of an intensive livestock unit will need to be framed (7.13).

72. Fish farming is a form of intensive livestock farming and should be subject to planning control (7.15).

Consultation by planning authorities

73. It should be mandatory on planning authorities to consult environmental health authorities, water authorities and appropriate specialists within the Agricultural Departments on proposals for intensive livestock unit developments (7.20, 7.21). Consideration should be given to whether consultation should be mandatory for other kinds of agricultural development (7.20).

Guidelines

74. Central guidance should be provided to planning authorities on the reduction of pollution risks from intensive livestock unit developments (7.29).

Control arrangements

75. Arrangements should be instituted for monitoring the pollution aspects attending the operation of intensive livestock units by appropriate specialists within the Agricultural Departments (7.42).

76. Local authorities should have powers to set in advance conditions on the operation of intensive livestock units and to take anticipatory action in the event of such conditions not being observed (7.43).

Consultation and grant aided developments

77. It should be a condition of the award of any grant for any agricultural development that may cause water pollution that the relevant water authority has been consulted and that its views have been taken into account (7.50).

78. The membership of Regional Panels should be widened; water authorities and other relevant organisations should be enabled to make representations to the Panels when these Panels are considering cases where grant aid has been refused on environmental grounds (7.52).

79. In considering applications for grant aid, the Agricultural Departments should take full account of pollution aspects in exercising their duties under Section 11 of the Countryside Act 1968 (or corresponding legislation in Scotland) (7.54).

8.33. **Agriculture and pollution (Chapter VIII)**

80. The initiative for action to deal with pollution caused by agricultural practices should rest with MAFF (8.9).

81. The organisation and functions of the agricultural advisory services should be reviewed to ensure that pollution aspects are adequately covered (8.26).

Acknowledgement

8.34. We wish to record our gratitude to all the staff of our Secretariat for their loyal and efficient service during our study. We thank our Assistant Secretary, Mr John Dore, and our Scientific Assistant, Dr Raymond Ward, for the assistance they have given to us in the preparation of this report. We particularly acknowledge our debt to our Secretary, Mr Lionel Rutterford, on whom much of the work of drafting our report has fallen.

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

HANS KORNBERG *(Chairman)*
SHIRLEY ANGLESEY
EIRENE WHITE
HENRY CHILVER
RICHARD DOLL
RALPH VERNEY
DAVID HENDERSON
PATRICIA LINDOP
MURDOCH MITCHISON
RONALD NICOLL
RICHARD SOUTHWOOD
JOHN COLLINGWOOD
JOHN MADDOX
RICHARD THORNTON
DAVID WILLIAMS

L. F. RUTTERFORD *(Secretary)*

J. H. DORE *(Assistant Secretary)*

June 1979

One of our members, Mr. Roy Grantham, was unable to take a significant part in our deliberations because of his other commitments. In the circumstances he decided that he could not properly sign this Report.

APPENDIX 1

MEMBERS OF THE COMMISSION

The membership of the Commission for the study of agriculture and pollution was as listed below. The Commission was reconstituted on completion of the study and those members whose terms of office ended at that time are indicated by an asterisk.

Chairman:

PROFESSOR SIR HANS KORNBERG, MA, DSc, ScD, DU, PhD, FI Biol, FRS

Sir William Dunn Professor of Biochemistry, University of Cambridge
Fellow of Christ's College, Cambridge
A Managing Trustee of the Nuffield Foundation

Members:

*THE MARCHIONESS OF ANGLESEY, CBE

Chairman of the Welsh Arts Council
Member of the Arts Council of Great Britain
Deputy Chairman of the Prince of Wales Committee
Member of the Independent Broadcasting Authority

SIR HENRY CHILVER, MA, DSc

Vice Chancellor of the Cranfield Institute of Technology
Member of the Commission on Energy and the Environment

*DR J. G. COLLINGWOOD, BSc, FI Eng, FI Chem. E

Fellow of University College, London
Council Member of the University of Aston
Member of the Food Standards Committee
General Secretary of the British Association for the Advancement of Science
Member of the Commission on Energy and the Environment

*PROFESSOR SIR RICHARD DOLL, OBE, DM, MD, DSc, FRCP, FRS

Regius Professor of Medicine, University of Oxford
Member of the Commission of Energy and the Environment
Member of the Hebdomadal Council, University of Oxford
Chairman of the Management Committee, Institute of Cancer Research

ROY A. GRANTHAM, ESQ
General Secretary of the Association of Professional, Executive, Clerical and Computer Staff
Member of the Executive Council of the Confederation of Shipbuilding and Engineering Unions

PROFESSOR PATRICK D. HENDERSON
Professor of Political Economy at University College, London

*PROFESSOR PATRICIA J. LINDOP, MB, PhD, DSc, FRCP
Professor of Radiation Biology, University of London Medical College of St. Bartholomew's Hospital
Chairman of the University of London Interdisciplinary Special Committee for the Environment
Chairman of the Society for Education in the Applications of Science

JOHN R. MADDOX, ESQ, MA
Director of the Nuffield Foundation
Member of the Genetic Manipulations Advisory Group

*PROFESSOR J. M. MITCHISON, ScD, FI Biol, FRS, FRSE
Professor of Zoology, University of Edinburgh

*PROFESSOR R. E. NICOLL, MSc, FRICS, FRTPI
Professor of Urban and Regional Planning, Strathclyde University
Advisor to UNDP and WHO
Director of the Glasgow Chamber of Commerce

PROFESSOR T. R. E. SOUTHWOOD, PhD, DSc, ARCS, FRS
Professor of Zoology and Applied Entomology, University of London
Head of the Department of Zoology and Applied Entomology
Director of the Field Station, Imperial College
Trustee of the British Museum (Natural History)
Member of the Agricultural Research Council, Research Grants Board
Member of the Advisory Board for the Research Councils
Member of the JCO Arable and Forage Crops Board
Governor of the Glasshouse Crops Research Institute

R. E. THORNTON, ESQ, JP
Member of the Thames Water Authority
Chairman of the Regional Land Drainage Committee
Member of the Ministry of Agriculture Regional Panel
Member of the Executive Committee of the County Landowners' Association and Chairman of the Agriculture and Land Use Committee

*SIR RALPH VERNEY, BT, KBE, JP
Vice Lord Lieutenant of Buckinghamshire
Forestry Commissioner
Chairman of the DOE Advisory Committee on Aggregates
Chairman of the Special Committee of the European Confederation of Agriculture on Agriculture and the Protection of the Environment

Appendix 1

THE RT. HON. BARONESS WHITE, MA, LLD

Chairman of the Land Authority for Wales
Member of the British Waterways Board
Chairman of the Environment Sub-Committee of the House of Lords Select Committee on EEC Legislation
President of the Council for the Protection of Rural Wales
Member of the University Grants Committee
Chairman of Coleg Harlech
Member of the Waste Management Advisory Council

D. G. T. WILLIAMS, ESQ, MA, LLB, LL.M

Reader in Public Law at the University of Cambridge
Fellow of Emmanuel College, Cambridge
Member of the Council of Tribunals
Member of the Clean Air Council
Member of the Commission on Energy and the Environment

APPENDIX 2

LIST OF THOSE WHO SUBMITTED EVIDENCE

Written Submissions were made by the following: those marked * gave oral evidence at formal Commission meetings; those marked † gave oral evidence during the Commission's visits.

Government Departments and similar bodies

*Advisory Committee on Pesticides (MAFF).

*Agricultural Development Advisory Service (MAFF).

Central Water Planning Unit (DOE).

*Civil Aviation Authority.

Countryside Commission.

†Department of Agriculture and Fisheries for Scotland.

†Department of Agriculture for Northern Ireland.

*Department of Health and Social Security.

*Department of the Environment.

†Department of the Environment for Northern Ireland.

†Forestry Commission.

*Ministry of Agriculture, Fisheries and Food.

†Scottish Development Department.

†Scottish Home and Health Department.

Welsh Office.

Research Councils

*Agricultural Research Council.

*Medical Research Council.

*Natural Environment Research Council.

Other Organisations

†Anglian Water Authority.

Association of Agriculture.

Association of Applied Biologists.
*Association of District Councils.
*Association of County Councils.
†Association of Local Authorities of Northern Ireland.
*Association of Metropolitan Authorities.
Association of Public Analysts.
Association of Scottish District Salmon Fishery Boards.
*British Agrochemicals Association.
British Crop Protection Council.
British Institute of Agricultural Consultants.
†British Pig Producers Federation.
British Poultry Federation Ltd.
British Trust for Ornithology.
British Veterinary Association.
British Waterways Board.
Cardiff University Industry Centre.
Central Electricity Generating Board.
Centre for Agricultural Strategy.
Confederation of British Industry.
Conservation Society.
Convention of Scottish Local Authorities.
Council for the Protection of Rural England.
†Council of Scottish Agricultural Colleges.
*Country Landowners' Association.
Ecological Foundation.
Environmental Health Officers' Association.
Farm and Food Society.
Farmers' Union of Wales.
*Fertilizer Manufacturers' Association.
†Fisheries Conservancy Board of Northern Ireland.
Food Manufacturers' Federation.

Game Conservancy.

Imperial Chemical Industries.

Imperial College, Department of Zoology and Applied Entomology.

Institute of Geological Sciences (NERC).

Institute of Water Pollution Control.

Institute of Public Health Engineers.

Institute of Water Engineers and Scientists.

International Agency for Research on Cancer.

Mother Earth Society.

National Anglers' Council.

National Association of Agricultural Contractors.

National Association of Waste Disposal Contractors.

*National Farmers' Union of England and Wales.

*National Farmers' Union of Scotland.

†National Institute of Agricultural Engineering.

National Society for Clean Air.

National Union of Agricultural and Allied Workers.

*National Water Council.

*Nature Conservancy Council.

Public Health Laboratory Service.

Pure Rivers Society.

Royal Agricultural Society of England.

Royal Institution of Chartered Surveyors.

Royal Society for the Protection of Birds.

Royal Society of Health.

Scottish Landowners' Federation.

†Scottish River Purification Boards' Association.

Scottish Wildlife Trust.

Shellfish Association of Great Britain.

Shetland Islands Council.

Society of Chemical Industry.

Soil Association.

†Solway River Purification Board.

Tay River Purification Board.

†Thames Water Authority.

Tweed River Purification Board.

†Ulster Farmers' Union.

Ulster Trust for Nature Conservation.

United Kingdom Agricultural Supply Trade Association Ltd.

University of London (Wye College).

University of Manchester (Department of Agricultural Economics).

University of Reading (Department of Soil Science).

Water Space Amenity Commission.

Wildfowl Trust.

†Yorkshire Water Authority.

Individuals

Mrs. G. Ashford.

Mrs. E. M. Chapman.

Professor Barbara Clayton.

Dr. E. F. Edson.

Sir Frank Engledow.

Professor S. R. Elsden.

Ian D. Hodge.

D. Houseman.

G. M. Hunter.

N. J. Hutchings.

Professor R. J. V. Joyce.

Professor F. T. Last.

Professor H. Lehmann.

Mrs. J. Machling.

J. S. Martin.

Professor K. Mellanby.

Sir Francis Pemberton.

Dr. D. Purves.

Dr. E. J. Tait.

M. A. Tyrell.

E. R. H. White.

Professor Gerald Wibberley.

Mrs. A. Wilks.

APPENDIX 3

DETAILS OF VISITS

1. Water Research Centre
   Stevenage, Hertfordshire, 15 April 1977.
2. Plant Pathology Laboratory
   Harpenden, Hertfordshire, 17 June 1977.
   including representation from:
   Rothamsted Experimental Station.
   Pest Infection Control Laboratory.
   Weed Research Organisation.
3. National Agricultural Centre
   Stoneleigh, Warwickshire, 7 September 1977.
   (Royal Agricultural Society of England.)
4. Anglian Water Authority
   Norwich, 20 and 21 September 1977.
   including representation from:
   Nature Conservancy Council,
   (East Anglia Regional Office).
   University of East Anglia, School of Environmental Sciences.
5. Humberside, 14 and 15 November 1977.
   Farms visited:
   Burton Pidsea Pig Producers Ltd., Roos.
   Constitution Hill Farm, Beverley.
   H. L. Hart and Sons, Aldbrough.
   Market Place Farm, South Cave.
   Meetings with representatives of:
   National Farmers' Union.
   British Pig Producers' Federation.
   Yorkshire Veterinary Society.
   Humberside County Council.
   Beverley District Council.
   Holderness District Council.
   Council for the Protection of Rural England
   (North Humberside Branch).
   Ramblers' Association.
   Friends of the Earth.
   Roos Anti-Pollution Team.
   Humberside Association of Town and Parish Councils.
   Beverley Health District (Humberside Area Health Authority).
   Yorkshire Water Authority.

6. Jealott's Hill Research Station
   (Imperial Chemical Industries,
     Plant Protection Division), 24 November 1977.
   including representation from:
     British Agrochemicals Association.

7. Plant Breeding Institute
   Cambridge, 6 December 1977.

8. Commission of the European Communities
   Brussels, 9 and 10 February 1978.
   Environment and Consumer Protection Service.

9. Germany and the Netherlands, 10–13 April 1978.
   Federal Republic of Germany:
   Meetings with representatives of:
     Ministry of Agriculture.
     Ministry of the Interior.
     Ministry of Health.
     Standing Council of Environmental Advisers.
   Netherlands:
   Meeting with representatives of:
     Ministry of Agriculture and Fisheries.
     Ministry of Public Health and Environmental Protection.
     Council of Environmental Health.
     State Water Authority (Ministry of Transport and Waterways).
     Institute of Waste Water Purification.
     Union of Water Boards.
     Gelderland Manure Bank, Veluwe.

10. Scotland, 8 and 9 May 1978.
    Meeting with representatives of:
      Scottish River Purification Boards' Association.
      Solway River Purification Board.
      Nithsdale District Council (Environmental Health Department).
      Council of Scottish Agricultural Colleges.
      National Farmers' Union of Scotland.
      Forestry Commission.
      Department of Agriculture and Fisheries for Scotland.
      Scottish Development Department.
      Scottish Home and Health Department.

11. Northern Ireland, 24 and 25 July 1978.
    Meeting with representatives of:
      New University of Ulster, Limnology Laboratory, Lough Neagh.
      Fisheries Conservancy Board of Northern Ireland.
      Foyle Fisheries Commission.

Appendix 3

Ulster Angling Federation Limited.
Association of Local Authorities of Northern Ireland.
Ulster Farmers' Union.
Northern Ireland Trout Farmers' Association.
Greenmount Agricultural and Horticultural College (and the Freshwater Biological Investigation Unit).
Department of Agriculture, Northern Ireland.
Department of the Environment, Northern Ireland.
Department of Health and Social Services, Northern Ireland.

APPENDIX 4

ABBREVIATIONS USED IN THE TEXT

ACAH	Advisory Council for Agriculture and Horticulture in England and Wales.
ACAS	Agricultural Chemicals Approval Scheme.
ACP	Advisory Committee on Pesticides.
ADAS	Agricultural Development and Advisory Service.
ARC	Agricultural Research Council.
ATB	Agricultural Training Board.
AWA	Anglian Water Authority.
BAA	British Agrochemicals Association.
BASIS	British Agrochemicals Supply Industry Scheme.
BFMIRA	British Food Manufacturing Industries Research Association.
BWA	British Waterworks Association.
CAA	Civil Aviation Authority.
CEGB	Central Electricity Generating Board.
CLA	Country Landowners' Association.
COSAC	Council of Scottish Agricultural Colleges.
CUEP	Central Directorate on Environmental Pollution (DOE).
CWPU	Central Water Planning Unit.
DAFS	Department of Agriculture and Fisheries for Scotland.
DES	Department of Education and Science.
DHSS	Department of Health and Social Security.
DOE	Department of the Environment.
EEC	European Economic Community.
EDC	Agriculture Economic Development Committee.
EHO	Environmental Health Officer.
EPA	United States Environmental Protection Agency.
FMA	Fertilizer Manufacturers' Association.
HSE	Health and Safety Executive.
ICI	Imperial Chemical Industries.
IGS	Institute of Geological Sciences (NERC).
ITE	Institute of Terrestrial Ecology (NERC).
MAFF	Ministry of Agriculture, Fisheries and Food.
MRC	Medical Research Council.
NAAC	National Association of Agricultural Contractors.
NCC	Nature Conservancy Council.
NERC	Natural Environment Research Council.
NFU	National Farmers' Union.

NWC	National Water Council.
PBI	Plant Breeding Institute (ARC).
PSPS	Pesticides Safety Precautions Scheme.
SSC	Scientific Sub-Committee of the ACP.
UKASTA	United Kingdom Agricultural Supply Trade Association.
WHO	World Health Organisation.
WRC	Water Research Centre.
WSL	Warren Spring Laboratory of the Department of Industry.

APPENDIX 5

THE AGRICULTURAL ADVISORY SERVICES

England and Wales

1. *The Agricultural Development and Advisory Service*

ADAS was set up in 1971, to bring together the scientific and technical services within MAFF which are concerned with agricultural production. It has four principal functions:

(i) To provide information and advice to farmers and growers to help them develop financially sound farm businesses.

(ii) To undertake research and development work and help to identify problems needing investigation and research.

(iii) To advise Government on the scientific, technical and business implications of policy proposals and their implementation.

(iv) To assist in the execution of measures such as statutory regulations relating to plant and animal health and hygiene, capital grant schemes and disease eradication schemes.

There are five constituent parts, namely the Agricultural Science, Agriculture, Land, Land Drainage and Veterinary Services. There are about 5,800 staff of whom about one third are in each of the Veterinary and Agriculture Services and one fifth are in the Agricultural Science Service. Only a small proportion of the staff of ADAS can be called general advisers, the majority are specialists in one of the many aspects of ADAS' work. Broadly speaking, the generalists, who need to be in frequent contact with farmers, form the staff of the 30 divisional offices which cover England and Wales. The divisions are grouped into 8 regions and it is the regional centres which provide most of the specialist support. There are also three central laboratories, each with a national responsibility—two Agricultural Science Service Laboratories and the Central Veterinary Laboratory (CVL).

2. Through his divisional office a farmer has access to officers of all five services and it is possible that some of his problems will require a multi-disciplinary approach to their solution. For example, a problem of trace element deficiency leading to crop losses and animal ill-health might involve general advisers (Agriculture Service), soil scientists and nutrition chemists (Agricultural Science Service) and Veterinarians. Where co-operation on particular subjects is necessary, one of the five services is designated as the "lead service" and assumes responsibility for the co-ordination of effort. The lead service on pollution matters is the Agricultural Science Service, the regional staff of which cover six disciplines:—Soil Science, Microbiology, Plant Pathology, Entomology, Nutrition Chemistry and Analytical Chemistry,

as well as the Regional Pests Service. For example, the Soil Scientists give advice and carry out R & D on pollution of soil and crops from industrial sources as well as from pesticides or farm waste. They are also much concerned with leaching from soils. The Microbiologists are particularly concerned with microbiological contamination of water supplies and animal feedingstuffs. There is also a specialist Farm Waste Unit with 4 scientific staff who act as a nucleus of expertise and guidance for the many other staff who deal with farm waste problems as part of their duties. At Science Service Headquarters there is a Pollution Scientist who acts as a focal point on pollution questions, both advising on policy matters and keeping a general over-sight on pollution R & D. Technical co-ordination on particular issues is achieved with a number of working parties, for example the Soil Scientists' Pollution and Waste Products Committee.

In addition to free advice, the Agricultural Science Service offers a number of specialist laboratory services, such as soil analysis, for which farmers pay a fee. Two of the national laboratories mentioned above are part of the Agricultural Science Service. One (at Harpenden) undertakes scientific work to prevent the introduction or dissemination of pests and diseases harmful to plants. The other (with headquarters at Slough) undertakes work on pests associated with stored food and on vertebrate pests (rats etc) which harm growing crops, stored food and public health. The Harpenden Laboratory provides the scientific secretariat for the Pesticides Safety Precautions Scheme and administers the Agricultural Chemicals Approval Scheme.

3. The Agriculture Service consists of a "front line" of general advisers supported by a number of specialist groups covering such subjects as Dairy Husbandry, Horticulture, Farm Management and Mechanisation. This service is responsible for 21 Experimental Farms and Horticultural Stations, spread throughout the UK to cover a range of soil and climatic conditions. These are used by ADAS for research and development projects and also for promotional activities aimed at the farmer. The Agriculture Service also contains the Horticultural Marketing Inspectorate which ensures that statutory quality grading schemes operate correctly.

4. The Land Service consists of surveyors, architects, geographers and technical support staff. It is responsible for advising farmers on land management, including the design, layout and construction of farm buildings. It advises central and local government on development proposals affecting agricultural land. It also assesses applications for capital grants. More generally, the Land Service is the lead service on conservation matters.

5. The Land Drainage Service advises on the removal of surplus water from agricultural land and its conveyance to the sea, and on the protection of land from flooding. It advises farmers on the provision of water supplies and also assesses schemes submitted by farmers for grant aid and by public authorities responsible for arterial drainage and flood protection. The service operates the Field Drainage Experimental Unit and cooperates with the ARC on such problems as the loss of nutrients through drainage.

6. The Veterinary Service is concerned with all animal health matters including the control and eradication of notifiable diseases, national disease control programmes and the import and export of animals and animal products. It provides the secretariat for the Veterinary Products Committee which licenses the production of animal medicines. The Veterinary Inspectors are based at the ADAS Regional Offices: many general veterinary practitioners are also employed part-time as Local Veterinary Inspectors. The Inspectors have specialist support in the CVL and in Veterinary Investigation Centres in the regions.

Northern Ireland and Scotland

1. The advisory service in Northern Ireland is broadly similar to that provided by MAFF in England and Wales. The service is provided by the Department of Agriculture for Northern Ireland: its advisers are located on a County basis and they are able to call upon specialist advice both from within their own unit or from the Research Divisions in the Department itself.

2. In Scotland, however, there is a considerable difference in the arrangements. There the advisory service for agriculture and horticulture is provided by the three Scottish Agricultural Colleges (The West of Scotland, the East of Scotland and the North of Scotland Colleges respectively). In addition to providing a comprehensive advisory service, the function of the Colleges is to provide an agricultural education, primarily up to diploma level.

3. The Colleges are registered as Limited Companies and are independent of the Department of Agriculture and Fisheries (DAFS), although they are in fact funded by that Department.

4. The main point of contact for farmers and growers wishing to make use of the College Advisory Service is with their local Area Officer. The Area Officers, in turn, are able to call on specialist advice from the specialist departments within the College (agronomy, animal husbandry, farm buildings etc) or from Experimental Farms run by the College. The Colleges, depending upon their location, tend to concentrate their research effort on differing aspects of agriculture. For example, the emphasis in the West of Scotland College is on dairying, that in the North of Scotland College, in association with the ARC Rowett Institute, is on slurry treatment systems.

5. A claim has been made for the Scottish system that it is free from any bureaucratic constraints since it is not involved in implementing legislation, nor is it bound to follow the DAFS line, although close contact between the Colleges and DAFS is maintained. The advisers are not involved with the processing of the various grant aid schemes; that is dealt with by DAFS Inspectors who will, however, seeking the advice of the advisers where appropriate.

6. Responsibility for the Veterinary Inspectorate in Scotland rests with MAFF, and not with DAFS.

APPENDIX 6

AGRICULTURE IN 2000 AD (Paper 1)

Ministry of Agriculture, Fisheries and Food

Synopsis

This paper looks at possible developments in UK agricultural practices and production up to the end of the Century against the background of the very great uncertainties which arise in considering such a period. These uncertainties—dealt with in Part 1—concern not only technological and commercial aspects of agriculture and food production within the UK, but also the possibility of major changes in the world balance of food supplies which could affect the strength of our need for domestically produced food. There are also uncertainties over possible developments in climate. This paper assumes, however, that current identifiable trends continue, with no climate change; and on this assumption, Part II assesses developments, within agriculture generally, in land-use, yields, mechanization, the application of fertilizers and pesticides and other related areas including dietary trends. Part III provides more detail on the same subjects for the main individual sectors of farming.

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I. Difficulties of forecasting to 2000 AD

Introduction

1. It is not possible to predict with any certainty developments in agriculture (or any industry) over a period of nearly 25 years. Present trends may change unexpectedly and there may be new trends and developments which we cannot now even begin to foresee. Changes can arise from all kinds of circumstances internal or external to agriculture: from developments affecting patterns of production including changes in the cost of inputs and in techniques used; from changes affecting consumption patterns; and from international as well as domestic developments. The Ministry considers that it is important to consider these uncertainties with some care and they are described more fully in paragraphs 2–9 below. Against this background, Parts II and III attempt a more positive view.

International aspects

2. The greatest uncertainty concerns the balance between the production

and consumption of food in the world as a whole. On the demand side, it seems likely that world population, on recent rates of increase, will double in about 35 years. Effective demand for food will grow at least proportionately if real incomes per head are maintained, and faster than population growth if real incomes per head rise. It is difficult to forecast to what extent population will increase or how effective demand will change, especially in developing countries.

3. Variability of climate is a particular feature of the tropical zones; and this could have a significant effect on the world food situation because the present age structure of tropical populations virtually ensures that by the end of the century there will be a much greater concentration of population in the areas of climatic instability. Moreover, there is no clear indication of the extent to which the results of scientific and technical research can help to improve production overseas and the extent to which new techniques and practices will be adopted, especially in developing countries. More generally, there could be changes in the availability and price of major inputs like energy (which is dealt with more fully in paragraph 7 below); entirely new forms of food might be developed; and there could be global political decisions of great importance in the long term.

4. With so many unknowns it is not possible to make any firm predictions about the world food situation; if many factors turn out favourable, farmers in the UK will be operating at the end of the century in a supply situation broadly similar to today's.* It is, however, prudent to note the real possibility that they might be under pressure to produce a much higher proportion of our total needs for food.

UK position

5. There are similar, if less great, uncertainties in the domestic position. The development of agriculture is closely linked with the exploitation of new technology. There are two stages in this. First, there is research discovery—where timing is quite unpredictable—and second, the application of the results. The rate at which developments occur can vary from time to time for a variety of reasons including, for example, the commercial incentive to innovate and the availability of finance for new capital investment. The technological developments which could influence our agriculture in the short to medium term are reasonably well known and understood; the main question is how rapidly they will be generally adopted in farming. For the longer-term, however, the position is less clear and there is a wide range of technological possibilities with implications which cannot now be foreseen. There could be entirely new developments, for example in genetic improvement, in animal management or in cropping techniques. There could also be technical

*This view is broadly in line with recent forecasts by the DOE Systems Analysis Research Unit. These suggest that, with population growth following the UN "medium" projections, with agricultural innovation remaining within the spectrum of techniques already demonstrated in the field and on two widely different scenarios for general economic growth, the international market environment within which UK farmers would be operating at the end of the century could be broadly similar to today's.

developments outside agriculture, for example, in new forms of industrially-produced food protein or through the commercial adoption of new methods of bread-making: these could affect agricultural production.

6. In practice, in the last 25 years or so, the improvement which we have seen in UK farming productivity and production has resulted from a combination of factors. These have included the increased application of energy, fertilizers and pesticides; the improvement of crop and livestock husbandry techniques; the work of plant breeders especially in cereals (which work is very easily applied on most farms because it simply means using seed of new varieties); and development in animal genetics coupled with the use of centralized artificial insemination (again easily applied by most farmers). It is not clear to what extent these factors will apply over the next 25 years; or whether other relevant developments may occur in different directions. For example, it cannot be foreseen whether progress in breeding improved plants and animals will be as rapid as in the past; or whether it will be possible to accelerate the take-up by farmers of improved husbandry techniques; or whether supplies of energy, fertilizers and pesticides will continue to be readily available.

7. The progress of UK agriculture since the war has relied heavily on fossil fuels, not only for farm-used energy, but also in the ancillary industries. All forms of energy seem certain to cost substantially more in real terms by the end of the century, when the real price of oil may have increased by a factor of two or more. This is bound to have an important impact on agricultural costs and practices, especially for those sectors of the industry which are energy-intensive. It can be assumed that new forms of energy will become available; but the question must arise as to how readily and economically they can be applied to agriculture. In this context, it should also be noted that some key items in agricultural growth like fertilizers and pesticides are based on fossil fuels.

8. There is also scope for major changes in food consumption patterns in the UK. These could result from a number of possibilities and might be associated with changes in the food processing and distributive trades, where the specific requirements of manufacturers and distributive organizations might of themselves impose new techniques and restraints on farmers. The economics of production, combined with concern over health, could lead to a shift in consumption from animal fats to vegetable fats; and economic factors could also lead to some replacement of meat protein by cereal protein or novel proteins (eg textured vegetable protein) particularly in manufactured meat products. There could also be a reduction in the availability of some tropical foodstuffs as rising living standards in developing countries lead to increased domestic consumption there.

9. Finally, the possibility needs to be recognized of developments which could affect the framework in which farmers operate. One possibility is of changes in the incidence of animal diseases which would require new measures

restricting the freedom of operation of farmers and so affecting costs and output. Changes in our climate could also have an effect. In the last 100 years —especially the past 30 years—our weather has been more favourable than that of any previous recorded period of comparable length. There is no evidence as to when changes may be expected; but variability is a major characteristic of climate and, when changes do come, it is assumed by scientific opinion generally that they will be adverse.

General

10. It will be clear from the preceding paragraphs that it is very difficult to make any long-term prediction of the future course of British agriculture; and that it would be imprudent to assume that the next 25 years may not see circumstances which will put much greater pressure on our domestic food production. It must be borne in mind here that the extent to which the maximization of UK food production may be sought at the turn of the century could influence both public attitudes to pollution from agriculture and the extent to which farmers could in practice reduce pollution. Nevertheless, this paper sketches a generalized impression of the possible pattern of UK farming by the turn of the century, on the assumption that the broad framework, including our climate, is similar to that which applies now and that present trends continue. This follows in Parts II and III. The official population forecast for 2000 AD has been used; and it has been assumed that the UK remains within the EEC. Within this long period, there will doubtless be important changes in the CAP; but it would be premature either to attempt to predict the form which the changes will take or to suggest that they would materially influence the nature or scope of the Royal Commission's present enquiry.

11. Part II looks at agriculture in general and Part III at individual sectors. At each stage, the paper first looks backwards briefly over the last 25 years (so as to set the scene and give perspective to the forward projections) and then looks forward at possible developments in consumption patterns and levels of production and at future developments in techniques. Attention has been drawn in particular to aspects of interest in the context of environmental pollution.

II. General survey of agriculture up to 2000 AD

The past twenty-five years

12. In this period, UK agriculture has significantly increased its contribution to feeding the nation. In 1975/76 our self-sufficiency in temperate products was about 65 per cent compared with about 60 per cent in the mid-1950s. This has involved a substantial change in technology. Agricultural operations today are very different from those of the immediate post-war period. Various pressures have given rise to these developments: economic forces have made farmers seek more efficient and cheaper techniques of production; a continuing outflow of agricultural labour has led to new farming practices; and changing market demands have exerted strong influence on the type of production

within various sectors. Agriculture, like other industries, has become more capital-intensive and this process has been associated with a reduction in some of its more traditional characteristics. These developments have been associated with some effects on the environment.

Future developments in production and consumption

13. A major factor affecting agricultural production is the volume and nature of domestic consumer demand. Given the low sensitivity of total food consumption to changes in real incomes, and the low growth in population which is currently being forecast, it seems likely that there will be only a fairly modest increase by 2000 AD in the total supplies of food moving into human consumption in the UK. The consumption of particular commodities will, however, be affected by a range of factors including, for example, changes in the age-structure of the population and developments like those involving novel foods. If the present trends were to continue, total consumption of some products (such as poultry meat, glucose, honey, cheese and pork) would increase quite considerably while the total consumption of some others (including butter, fish, mutton, lamb and sugar) could show a decline. But it should be emphasized that over such a long time scale any change from the present trend could produce a markedly different picture.

14. Given UK food consumption, the UK production of particular commodities is determined by the availability of land and other resources; by developments in yields, feed conversion ratios* and animal stocking densities; and by the potential for exports or import substitution. With a few possible exceptions (such as lamb, eggs, poultry and specially grown, high quality produce like malting barley and malt), the UK seems unlikely to develop a significant export trade in primary agricultural products, although exports of processed foods (many of them, eg biscuits and frozen foods, based on home-grown products) are likely to continue to increase. However, the combination of the modest overall change in total consumption and the net effect of land losses and changes in efficiency (which are discussed in later paragraphs) does indicate scope for import substitution in temperate products and a greater overall level of self-sufficiency by the end of the century.

Future developments in farming practice

15. Farming can be expected to continue to make rapid improvements in its efficiency, and total output may be substantially greater by the end of the Century than today from a land area about 4 per cent — 7 per cent smaller, reductions in land being offset by much greater yields and stocking densities. These developments will be associated with a steady increase in the size of the average farm unit, whether owner-occupied or tenanted. While a slowing down in the outflow of labour from agriculture is to be expected, the trend towards greater mechanization will continue, with increasing emphasis on sophistication in the equipment used and in the skills of those who use it. The

*The feed conversion ratios for meat-producing animals are the ratios of weight of feed consumed to liveweight gain produced.

need to use specialized machinery to the full could lead to a further fall in the number of separate activities per farm. There is likely to be an accelerated trend towards growing crops on soils where their production can be fully mechanized and the movement towards greater specialization will continue. But there will be a continuing place for the viable mixed farm, but with a smaller number of separate activities.

16. While a wide range of alternative patterns of regional specialization is agronomically possible in the UK, there should not be much change from the present basic pattern unless there are dramatic changes in the relationships between costs and returns for different commodities or in other factors, eg patterns of climate. Thus, the predominantly arable areas in Eastern England, the Midlands and the South of England can be expected to continue on a mainly cropping system, because the agricultural infra-structure of these areas would make it difficult to revert to grazing livestock production. In the same way, grass farms in the more Westerly parts of the country will not show any major swing to arable production, even where the soils are suitable, because of the existing heavy investment in livestock facilities and the high initial costs of re-equipping to grow crops. The hill and upland areas will continue to be primarily areas of extensive grazing where the dominant enterprise will be livestock production. In all areas, increasing specialization on farms may tend to accentuate regional differences in land use.

17. In arable farming, while the possibility of the development of new crops cannot be completely discounted, major new activities seem unlikely. Potential candidates such as grain maize, sunflowers and lupins already give much higher yields in other parts of the EEC, and any advances made here are likely to be outweighed by progress made in production areas better adapted to these crops. There is no reason why some crops at present grown on only small areas in this country—for example, green field vegetables, leguminous crops (which do not require additional nitrogenous fertilizer), forage maize and fodder roots used as replacement for other feeds—should not be grown more extensively if demand grows or economic circumstances favour this. The use of fertilizers and pesticides will be of continuing and increasing importance on arable farms but with more precise application techniques. There will also be an increasing demand for water by agriculture, both for irrigation and for livestock.

18. In grassland livestock farming, one of the main changes is likely to be the greater concentration of dairy farming on fewer and larger farms. Within the reduced total area available for agriculture, grassland seems likely to occupy a slightly lower proportion of the total, but it will be more intensively managed. The main features of this intensification will be higher stocking densities and substantially greater applications of nitrogenous fertilizers to grassland than take place today. More livestock (including pigs and poultry) will be kept in bigger units and more cattle and some sheep will be housed in the winter instead of remaining outdoors. As a result, there will be larger quantities of effluent to be disposed of, some in the form of slurry; but further

developments in effluent treatment and handling, including improved usage as manure or in recycled form as animal food, are to be expected. As for intensive livestock units, the Ministry expects that pigs will increasingly be located in largely arable areas and does not foresee much change in the overall pattern of poultry production.

III. Further information about individual sectors

Crop production: past and present

19. Developments in arable farming in the last 25 years or so have been far-reaching. The substitution of capital (in the form of machinery) for labour has made possible a very substantial reduction in the labour force to the point where on average one man is now employed on every 81 hectares of arable land compared with one man to 16 hectares 20 years ago. The other main consequence of the development and introduction of specialist machines has been a move towards a larger scale of operation. Not only have farm businesses become bigger but they also carry fewer enterprises—thus providing the opportunity to achieve economies of scale in the use of machinery and other specialized resources. The number of enterprises on individual farms in predominantly arable areas has dropped by rather more than half since the war. This has affected the use of cereal straw, which had been mainly used as feed or bedding for livestock in mixed farming systems: the trend to more cereals and less stock on arable farms led to a surplus of straw (of which much is now burnt). New uses are unlikely to take up more than a part of the surplus straw that will be available over the next decade, and in-field burning is therefore likely to remain a necessary part of intensive cereal growing.

20. Important changes have also been taking place—and are still occurring—in crop production. With the availability of greater power for cultivation, improved crop varieties, more precise chemical treatments and better handling, processing and storage facilities, a programmed approach to crop production is being developed which makes it possible to specify more precisely the nature and timing of the operations needed to grow produce of a stated quality for a given market. A major contribution has come from plant breeding, which has provided varieties capable of responding to high fertilizer treatment, suited to mechanized harvesting and of the quality needed for different markets.

21. There have also been important changes in cultivation methods. Tractors with greater power and implements of larger size now enable operations to be done speedily when soil conditions are suitable; and the development of no-cultivation or minimum cultivation techniques for crops reduces the energy needed to grow them. Moreover, there is increasing evidence that the longer these techniques are practised, the greater is the accumulation of organic matter in the top few inches of the soil, thus leading to a more stable soil structure less susceptible to damage from extremes of climate.

22. The key to this development has been the availability of effective herbicides. Indeed, the introduction of herbicides as an aid to crop production

has probably been the major innovation in post-war agriculture. Indeed chemicals have made a major impact in controlling all pests, and the industry is now in a situation of considerable reliance on chemical application the spraying machine has become a very important implement. At the same time, fertilizer use has grown in parallel with the introduction of varieties having the potential to respond to a higher nutrient supply.

Crop production and consumption: future developments

23. A significant increase in cereal production can be expected by the end of the century. No substantial change is expected in the area of land devoted to cereals, but yields will continue to rise. Total consumption of cereals will probably increase, with the main increases in the brewing and distilling sectors. Human consumption of cereals in the form of bread, flour etc seems likely to decline. A significant proportion of cereals will continue to be fed to livestock, although continued improvements in feed conversion ratios might be expected broadly to offset any increased demand for cereals due to the possible expansion of pigmeat and poultrymeat production. Overall, our self-sufficiency is expected to increase but with the UK continuing to be a net importer of some cereals and an exporter of high-quality malting barley and malt.

24. For potatoes, the total consumption over 25 years or so seems likely to fall slightly; and if it is assumed that the present level of self-sufficiency continues and that there are no major new developments such as the introduction of a potato starch or potato alcohol industry, the likely increase in yields will permit a substantial reduction in area. For sugar beet, there seems unlikely to be any significant fall in area, partly because the crop will continue to have an important part in arable rotations. Only a modest improvement in yields is envisaged, but given the expected fall in demand, there should be a higher level of self-sufficiency. In field vegetables there could be a significant increase in consumption and production, which, even allowing for yield improvements, could involve an increase in area. For fruit there may be only a moderate increase in consumption, which with increased yields might be accompanied by some fall in the area used. Arable by-products are likely to be increasingly valued for livestock feed or industrial uses: vegetable wastes and sugar beet tops are readily eaten by livestock and can replace purpose-grown forage, thus saving land.

Crop production: future developments in techniques

25. The present trends towards minimum cultivation systems is expected to continue. These systems, and particularly the direct drilling method, will demand the increased use of herbicides such as glyphosate and paraquat to kill perennial and broad-leaved weeds before crops are sown. However, although farming will continue to be dependent on herbicides and their use will widen as materials of greater selectivity are developed, the total use of chemicals for weed control may increase less rapidly than might be supposed from these trends. Soils are gradually becoming less burdened with weed seeds; and already, on fields where weed infestation is light, the stage has been reached where the phytotoxic effect of a herbicide can reduce yield more

than its weed-killing effect increases yield. For instance, there is evidence that, for some root and vegetable crops, a combination of herbicide and hand-weeding is more economic than several treatments with herbicide. The increasing cost of herbicides, which are largely derived from fossil fuels, may make this combined approach more attractive. There should also be major improvements in uniformity of spraying, so that less chemical per hectare will be needed for control (resulting from improvements in spray boom design, controlled droplet application etc); in the development of more active chemicals (so that less is needed); and in bio-degradable chemicals (so that activity time is limited). There should also be developments in techniques like irrigation, particularly trickle irrigation techniques for field crops and soil-less cultivation of glasshouse crops (eg hydroponics*, including nutrient film techniques).

26. The use of other pesticides, notably fungicides, is likely to increase as production methods become more precise and crop quality requirements more stringent. The number of treatments will, however, vary from year to year as better forecasting of disease outbreaks etc increasingly guides farmers on the economic use of pesticides. Pesticide manufacturers, in the interests of improving their products, will also seek to produce materials which are bio-degradable, with fewer environmental side effects; and the quantities of chemical applied per unit area will be less per treatment due to more effective methods of application and improved formulations. There will be a major move towards integrated control systems in which pest control will be based on the combination of resistant varieties, improved agronomic practice and specific chemical usage. There is unlikely to be a major reduction in the use of pesticides as a result of developments in biological control, except possibly in the glasshouse sector.

27. The agricultural chemical industry is relatively young and the developments which have taken place in the past 25 years suggest that there is much new technology to come—for example in the development of chemical soil sterilants which have a markedly beneficial effect on crop yields by controlling soil-borne pests, and of desiccants applied to forage crops just before harvesting, which could greatly speed up the conservation process and make it much less weather-sensitive.

28. It is also to be expected that plant breeding will continue to make major contributions to agricultural productivity by providing new varieties of higher yield and quality potential and also by manipulating the structure of some plants (eg fruit and vegetables) to make them better adapted to mechanical harvesting and handling. A particular objective will be more durable resistance to disease (with the aim of reducing the need for pesticides), but recognizing that there will be a continuing battle against the evolution of new strains of pathogens.

*Hydroponics is the production of plants where the roots are growing solely in solutions of nutrients.

29. Most arable crops already receive fertilizer applications at a near optimum level for present yields. Rates of use may increase somewhat to allow for the higher yield potential generated by other technology. Farmers will in future attempt to gear their fertilizer use more closely to the needs of specific crops on specific soils, and efficiency may be increased by split application linked to the growth of the crops so that residues and leaching are reduced.

30. Other factors which will be important in improving productivity in the arable sector include new seed technology which will improve germination and vigour and hence give more predictable plant establishment, thus permit ting fuller exploitation of the photo-synthetic energy available from the sun by the manipulation of crop spacings. This will also assist in meeting the quality specifications required by consumers. There will be further advances in the understanding of the nutrition of crop plants which will optimize the use of fertilizers and exploit the improved genetic potential resulting from plant breeding.

Dairy farming: past and present

31. The two most significant advances in dairying have been in milk yields per cow and in labour productivity. The average annual yield per cow now stands at about 4,320 litres compared with 2,730 litres just after the Second World War. Much of this improvement has resulted from the changeover to the Friesian breed, which now constitutes a very high percentage of the national herd. There is less disease in dairy herds; tuberculosis has been virtually eradicated and the programme against brucellosis is now well advanced. Improvements in cow husbandry and medication offer a means of reducing disease problems such as mastitis. Artificial insemination has contributed to the raising of the genetic potential of the herd and there have been major advances in dairy nutrition and in management. Finally, increasing sophistication in building design and milking machinery has made it possible for one man comfortably to milk over 100 cows—which is far more than when milking was done by hand. Despite the improvement in cow performance, there has been a reduction in the area needed by each animal, as a result of heavier fertilizer use coupled with improved grazing and conservation techniques, so that each cow on average now uses 0.6 hectares, compared with one hectare immediately after the Second World War.

32. Problems with disposal of excreta from dairy herds have grown, partly because of increasing herd size, but mainly as a result of the marked shift from bedding on straw (producing traditional FYM) to housing in cubicles and the use of slats, with a liquid slurry to be disposed of. There is the risk of pollution from leakage, overflow and smell from slurry lagoons, and from run-off of slurry spread on wet fields. Moreover, as the majority of dairy cows receive silage during the winter as part of their diet, there is a risk—which should not, however, be exaggerated—of pollution of water courses etc by the effluent where silage has been incorrectly made or where there is inadequate provision for the collection of the silage effluent.

Dairy farming: future developments in production and consumption

33. It is possible that there will be a considerable increase in milk production, leading—since consumption is expected to rise only slightly—to a much higher level of self-sufficiency in the UK in milk and milk products. There is already scope for much higher yields per cow on the basis of existing technology; and milk production is at present expanding sharply on account of higher yields. If this trend were to continue, a total dairy herd of the present size could be producing perhaps 25 per cent more milk by the end of the century and from a much reduced area per cow. But it is possible, on the other hand, that the trend will change and that following a period of relatively fast improvement in yields per cow, there may be a further period when expanded production is brought about by increases in the dairy herd.

Dairy farming: future developments in techniques

34. Individual dairy herds will continue to grow in size as smaller producers leave the industry and the remaining herds expand to make full use of specialized labour and equipment. The average herd size could well double by the end of the century. The genetic potential of the national dairy herd will continue to rise, partly as a result of greater use of Holstein blood but also through better overall selection. General standards of management are expected to improve, particularly in relation to disease control, regular breed ing and the nutrition of cows. Ingredients in the ration are unlikely to change radically, but higher quality forage resulting from improved conservation technology will make a greater contribution to the feed requirements of cows, although efforts to improve management and husbandry and to achieve higher yields will probably bring an increased use of concentrates* per cow.

35. There is great potential for increased fertilizer application, particularly of nitrogen, to improve the output of grassland, and higher dressings are therefore likely on grass. As a result of higher fertilizer use, the land area per cow could fall by as much as one third from the present 0·6 hectare. The average rate of nitrogen used on dairy farms could well increase substantially. The trend towards cubicle housing of dairy cows will continue, with virtually all new or modernized units adopting this system. This will result in an increase in slurry handling, but techniques of applying slurry to land—and perhaps of separating and handling separately the liquid and solid fractions—may develop to the point where nuisance from odour or air contamination is no greater than from conventional manure handling systems involving FYM. Environmental problems are therefore likely to decline.

36. The present trend towards more silage making at the expense of hay could decline and even be reversed as improved hay-making methods are adopted: the use of improved balers coupled with barn-drying has already removed much of the weather risk from hay-making. This could have the advantage of reducing the risks of pollution from silage effluent.

*Concentrates are concentrated animal feedingstuffs supplying protein or energy.

Poultry and pigs: past and present

37. The poultry industry has undergone massive change. Flock size is tending to polarise either towards very large operations fully integrated with feed supplies and market outlets or to medium to small units aimed to a large extent at meeting farm-gate trade or selling direct to retailers or markets. Poultry have largely gone indoors into environment-controlled houses where—especially on the larger units—feeding, cleaning, watering and egg collection are mechanized. Genetic development has been dramatic and almost all poultry stock are now supplied by specialist breeding firms which have produced hybrid strains capable of very high egg production or growth rates. Most table chickens and turkeys are produced on intensive systems, with an 8-week growth cycle for chickens replacing the earlier 24-week fattening period. Diets have continued to improve: in more efficient enterprises one kg of poultry liveweight is produced with an input of 2 kg of high energy meal.

38. These changes in poultry production methods have created problems, some visual, but mainly those associated with disposal of the excreta from large poultry enterprises. Some of these are no longer linked with land under the same ownership or occupation on which the excreta can be spread; and there can be odour problems, particularly when excreta is heat-dried before it is moved from the unit. Developments which help to overcome these problems are set out in paragraph 43 below.

39. The pig industry has changed more slowly than the poultry industry, the trend being towards larger units. Efficiency has increased markedly: the feed conversion ratio has fallen from nearly 5 kg of meal per 1 kg liveweight in 1946 to just over 3·5 kg today, while in the same period the annual number of pigs produced per sow has risen from 11 to 16. Since the War the number of breeds in common use has fallen, and breeding policies are aimed at satisfying the specialist markets for pork, bacon and heavy hog carcasses. Like poultry, pigs have largely gone indoors into controlled environment houses, with increasing automation in feeding and dung removal. The breeding stock is similarly being increasingly produced by specialist breeding companies, which can more readily apply modern genetic science so as to produce more productive strains than could the large number of individual breeders previously operating. Nevertheless, the improvement brought about by individual breeders will remain important. As with poultry, the trend towards a greater concentration of pig production has had environmental implications, with perhaps greater problems because of the nature of the excreta.

Poultry and pigs: future developments in production and consumption

40. In both eggs and poultry we are already self-sufficient. Egg consumption seems unlikely to change much, but poultry meat consumption could rise fairly rapidly and the total numbers of poultry by the end of the century could show a substantial increase. It seems likely that pork consumption will also increase substantially by then, although little change is to be expected in the

consumption of bacon and ham. These developments should encourage some expansion of pig production in the UK.

Poultry and pigs: future developments in techniques

41. Little change is foreseen in the overall pattern of poultry production. The large production groups may grow in size, but the small units which meet the farm-gate trade seem likely to remain. New technology seems likely to refine rather than change existing practice. To date, in the egg sector of the industry, many of the findings of research and development have been adopted and the best flocks achieve yields close to the genetic potential of the available stock. Higher average yields will however come as more producers adopt new techniques. Developments in the mechanical handling of feed, eggs and manure will facilitate labour efficiency.

42. In the poultry meat sector, research and development work on husbandry has been limited because the broiler industry is fairly new. But progress can be made relatively quickly for broilers and benefits show up within a 5-year period. There is the prospect of further significant improvement in feed conversion ratios in the next 25 years for broilers and other poultry.

43. Effluent from poultry houses will become increasingly valued for fertilizer or feed. Poultry manure is high in nitrogen and the economic advantage of substituting it for inorganic nitrogenous fertilizers will increase as the latter become more costly due to increasing oil prices. Dried poultry manure has so far only been used on a limited commercial scale as a protein supplement in animal feed, but more may be used if conventional sources of protein become more expensive. Wider use will probably be made of a recently-developed improved design of poultry house in which the excreta is air-dried naturally, making it easier to handle and spread and removing the odour problem; and greater attention will be given to siting new poultry units in suitable locations with adequate access to land for effluent disposal.

44. In pig production, it is to be expected that both breeding and finishing* units will continue to grow in size, but with a limit on the scale of individual units. This increase in size will offer opportunity for use of better specialist management and equipment. The annual number of pigs produced per sow (which is a key factor in efficiency) will continue to increase. The earlier weaning of piglets is likely to become more widespread and very early weaning, ie at less than 2 to 3 weeks of age, may become economically practicable. This earlier weaning could reduce piglet mortality and shorten the breeding cycle of the sow. In both breeding and finishing herds, better management (including environmental control in piggeries) will result in a saving in feed inputs. Already most litters of pigs carry the acknowledged benefits of planned cross-breeding; and feed conversion efficiency and carcass quality will improve further as the genetic improvements flow down through the national herd. There is unlikely to be a return to solid manure handling system for pigs,

*Finishing is a term used to describe the final stage in livestock production when an animal is being fattened before slaughter.

although because of environmental considerations some units will need to continue to handle manure in this form: a large proportion of pig manure will therefore continue to be handled as slurry. Pig units will increasingly be located in the larger arable areas, where feed grains are produced and where effluent disposal on land is easier.

Beef and sheep: past and present

45. There have been significant gains in productivity in these sectors during the past 25 years. By similar techniques to those described for dairy cows, more stock are now carried on a given area, although it has been less easy to adopt such methods on the common hill land which carries a large proportion of the sheep flock. Beef cattle are slaughtered at a much lower age than used to be the case, following a better understanding of the nutritional requirements of the animal, improved grazing techniques and the production of better quality hay and silage. The use for beef production of suitable calves from the dairy herd has become an important feature of the industry through development of better rearing and finishing systems which can produce a quality product from calves once regarded as unsuitable for beef production. The wider use of bulls of beef breeds, including those of late-maturing British and Continental breeds, for crossing on dairy cows also provides cross-bred calves which finish at higher weights at a given age. Pollution from beef enterprises presents much less of a problem than from dairy cattle; herds tend to be smaller and more beef cattle are bedded on straw. But intensification of beef on slatted floors and the making of silage for feed can present problems similar to those in the dairy herd (see paragraph 32 above).

46. Progress has been rather slower in the sheep sector. The two key factors are lambs weaned per ewe and the number of ewes carried per hectare. Both have improved, but by considerably less than could be the case if known technology were more widely applied. The main pollution risk from the sheep sector is in the disposal of the residual liquid from sheep-dipping; but farmers are advised on effective methods of dip disposal.

Beef and sheep: future development in production and consumption

47. Total consumption of beef may increase only very slightly between now and 2000 AD; and we seem likely to continue to supply a large proportion of our own requirements of fresh beef, although there will be some need for imports of specialist cuts, particularly for manufacture. However, it is difficult to assess likely developments in numbers of beef cattle by 2000 AD, partly because much of any increased production could be met by an increase in the average weight at slaughter and partly because beef production will continue to be closely related to the dairy industry. Production of mutton and lamb is expected to rise despite the fall in total consumption, with an increase in self-sufficiency reflecting some combination of lower imports and higher exports.

Beef and sheep: future developments in techniques

48. No dramatic new technology is foreseen which will have a major impact

on beef cattle production. The structure of production and the pattern of marketing are tending to become more formalized with a trend towards more standardized production. The application of better systems of feeding will improve the conversion of feed to meat, especially if the present trend towards leaner carcasses continues. Forage maize could become a more important crop in the southern half of the country. Stocking densities will increase, and by the turn of the century the area needed to raise a beef animal could be reduced by as much as one quarter. The Ministry also expects to see progress in terms of yield and calf production, the use of ovulation control, and reduction in losses of young animals.

49. No great change in sheep production techniques are foreseen, although some farmers may adopt higher-cost intensive methods to produce out-of-season lamb which could attract higher prices. If present trends in costs and returns continue, there may be more flocks producing three lamb crops in a two-year period. Stocking densities and lambing rates should also continue to rise; also the present trends towards the improvement of hill land will not only enable more ewes to be carried in some circumstances but will also lead to better ewe nutrition, improved lamb production and more finishing of lambs on the hills. Better application of existing knowledge should lead to a reduction in lamb losses soon after birth.

IV. Summary

50. There are so many unknown factors in the next 25 years that forecasts cannot be made without heavy qualification. This paper sets out an assessment following a central course between a wide range of possibilities which are more extreme. The future of UK farming could prove to be dramatically different from that foreseen in this Paper, for example if there were changes in climate here or abroad; or serious food shortages overseas; or restraints on production here because of fuel shortages or the spread of animal diseases.

51. Assuming that present trends continue and that the present broad framework is maintained, the Ministry foresees further improvement in efficiency, with higher yields and stocking densities, and a substantial increase in output from bigger and more highly mechanized farms using less land overall, with fewer separate activities on each, and using a smaller labour-force. There will be less, but more intensively managed, grassland; more livestock will be in big units; but there will be little change in the current pattern and location of crops.

52. In arable farming, trends to minimum cultivation are expected to continue. The use of fertilizers and pesticides will have increasing importance; but with more precise application techniques and other improvements, there will be only a moderate overall increase in the total volume of chemicals used. In dairying, the Ministry expects bigger herds, improved yields, greater use of fertilizers and a continuing trend to cubicle housing. No further dramatic changes are expected in the overall pattern of poultry production; pig units

will continue to grow in size; and efficiency in both pigs and poultry will improve further. Stocking densities of beef cattle and sheep will rise.

AGRICULTURE IN 2000 AD (Paper 2)

(i) requirement for self-sufficiency in temperate food;
(ii) adverse climatic changes;
(iii) substantial increases in energy costs;
(iv) increase in fertilizer requirements;
(v) developing resistance to pesticides; and
(vi) new developments in techniques.

Introduction

1. Our first paper on Agriculture in 2000 AD was based on the assumption that present trends would continue. The Commission has asked for the analysis to be extended on a 'scenario' basis and has indicated six factors (see above) which they hoped to see covered in the further analysis.

2. *Approach.* The original paper stressed the uncertainties involved in forecasting developments in agriculture, as in any other industry, over a period of nearly 25 years. These reservations apply equally to this paper. Indeed, the difficulties of forecasting increase if assumptions involving significant changes from past trends are made, because the changing inter-relationships between different sectors of the economy cannot clearly be foreseen. For example, a substantial shift in energy prices would affect virtually all industries and would also have direct effects on consumers; climatic changes too would have major effects outside agriculture. Agricultural Departments are not in a position to assess the possible effects of such changes in sectors other than the agricultural and food industries; yet effects on other sectors could doubtless materially modify the direct effects on those industries.

3. Subject to those reservations, this paper seeks to indicate in general terms the ways in which developments in agriculture might diverge from those outlined in the original paper if certain assumptions were varied on lines mentioned by the Royal Commission. Like the original paper, the approach is qualitative and represents no more than the informed estimates of those within the Ministry who have relevant contemporary knowledge.

4. The Ministry wishes to make it clear that nothing in the present paper is intended, or should be taken, to represent a Ministry view that any of the assumptions made in the original paper were unsoundly based. That paper reflected the best judgement of most likely future trends. The probability that the future will reflect one or more of the alternative scenarios set out below is not, in the Ministry's view, high.

5. In Parts I, II and III below, the Ministry considers separately each of the

first three variations in its original assumptions suggested by the Royal Commission. As the remaining points raised by the Royal Commission are rather different in nature, being more specific and tending to overlap with other evidence given or being given by the Ministry, these are discussed separately in Part IV.

I. Possible implications of virtual self-sufficiency in temperate foods

6. If extreme external circumstances required the UK to achieve self-sufficiency in temperate foods, it is possible that, as in both World Wars, the Government would have to introduce food rationing and would have to accord food production a relatively higher priority than obtains at present by comparison with many other factors, including environmental considerations. In the most extreme situation we should not only have to be self-sufficient in temperate foods but would also be obliged, as far as possible, to grow domestically foods which would replace the nutritional value of the non-temperate foods we now import. These are not, however, the sort of situations envisaged in paragraph 4 of the Ministry's original paper, and their effects could only be considered in detail on the basis of a number of assumptions about the nature of the emergency. The Ministry has therefore assumed that this is not the kind of alternative scenario which the Royal Commission has in mind.

7. When the Ministry referred to "the real possibility" that farmers "might be under pressure to produce a much higher proportion of our total needs for food", it had primarily in mind circumstances in which the world demand for food was gradually but noticeably outpacing world supply. This would imply a distinct upward shift in the trend of world food prices in real terms although, since world food markets tend to fluctuate significantly because of varying harvests, there would probably still be years in which prices were relatively lower. But shortages and high prices (of the type witnessed in 1974–75) would under this scenario become more frequent and more severe. Whilst the effects might differ from product to product, there is no reason in principle to expect that only temperate foods would be affected. In practice, since population increases in the developing world seem the most likely factor to set such a process in motion, it is to be expected that staples, such as cereals and rice, would be affected more directly than products such as beef and non-temperate fruit.

8. Any such development would almost certainly bring forth—in response to price and without Government intervention—additional production in all developed countries: and given that the European Economic Community as a whole is already self-sufficient in virtually all temperate foods—and probably has potential for substantially greater output if necessary—the extent to which the UK would be affected by shifts in world supply and demand in those (ie temperate) foods is not clear. Nevertheless, if for this or other similar reasons, the UK found it desirable or necessary to increase its own self-sufficiency significantly in the next two decades or so, we might expect developments rather along the following lines.

9. If, as we assume, any need for greater self-sufficiency in food would emerge gradually, the economics of agricultural production would tend to become more favourable, giving a price incentive to farmers to increase output, without necessarily implying increased controls over the nature and scale of production patterns. Economic pressures alone would probably slow down the present rate at which agricultural land is being lost to other uses (including both development and forestry), but this is an area in which government might also act. Clearly there would be little pressure to increase production of those products for which we are already totally or largely self-sufficient (such as potatoes, eggs, poultry, pork and barley) except to the extent that they were needed to replace other imports (such as barley to replace maize as an animal feed) or to reflect any dietary changes. And, if the price was right, we might continue to import some items—such as lamb from New Zealand during our winter—which complement our own production. The following assessment also assumes that there would be no constraint on farm inputs, particularly fertilizers and machinery (which would not necessarily be the case in a true emergency, particularly if it coincided with, or was precipitated by, a world shortage of energy).

10. The main change in the balance of enterprises would probably be that crops giving products suitable for direct human consumption would increase to the extent necessary to satisfy the nation's needs. Thus vegetable output, in which we are at present about 75 per cent self-sufficient, would expand to satisfy our present total requirements and perhaps also to replace some other items in our diet. Some dietary change might occur with more emphasis on cereals, vegetables and fruit, although the nutritional needs of the population could still be met. Cereal production might change to the point where this country was producing much more of its own bread wheat. This might mean a loaf of a different kind, although by the year 2000 technology might have overcome the problems which at present limit the proportion of home produced wheat in the grist.

11. Of the livestock enterprises, those which are grass based would tend to become more important, whilst those which rely on grain feeding would probably contract. Milk production would probably increase but with greater dependence on grass and forage feeds. Similarly beef would be produced largely from grass and intensive grain-fed fattening of beef would disappear. Changes in the sheep enterprise would probably be minimal in technical terms other than the adoption of improved technology to increase prolificacy and stocking density. There would be a big incentive to produce more from grass by greater use of fertilizer and by better husbandry, both in conserving grass products and in more intensive grazing systems. There are bound to be further developments across the whole field of this technology by the year 2000, but simply by the application of present knowledge, ruminant production from grass could increase greatly, particularly in the upland areas of the country, if economic conditions were more favourable.

12. Intensive grain-fed livestock enterprises would decline, pigs being

affected more severely than poultry, because the latter are the more efficient converters of feed. Some of the decline in pigs could, however, be reduced by making maximum use of household and other wastes, while current research suggests that it might be possible, by recycling treated pig manure, to reduce the need for supplementary protein in the diet. The contribution to total food supplies from garden and allotment production could perhaps become as significant as it did during the war.

13. Human food crops such as wheat, potatoes, vegetables, fruit and sugar beet would therefore be grown on an expanded acreage, although much of the west and north of the UK would remain in grass, with livestock production being expanded largely through the greater use of fertilizers and improved management systems. It is probable that national policy would aim for a higher carry-over of stocks both of food and of animal feedingstuffs so as to minimize the effects of year-to-year variations in crop production. This would apply both at the farm level (where in the drought years of 1975 and 1976, livestock farms with reserves of hay and silage fared best) and at the national level (where reserves of sugar were used to reduce the impact of the 1974/75 shortage). The reserves in the EEC intervention stores could help to provide a buffer against fluctuations in food production within the EEC.

II. Possible effects of adverse climatic changes

14. For most of the last 150 years, the UK has imported about half its food from areas as geographically dispersed as North America, Argentina and Australasia, thus reducing the risk of shortage due to climatic failure. That risk must tend to increase to the extent that we move towards greater reliance on production from the geographically-limited area of the UK and on imports from the geographically-linked EEC area.

15. Whether the climate is changing or not, agriculture could benefit significantly from better short and medium-term weather forecasting. This would improve the tactical decisions in agriculture—for example in sowing and harvesting, in date of turn-out of stock and in frost control measures—which can have a major influence on final yields. It would in fact be more valuable than better long-term forecasting since, for example, a warning that rainfall is likely to be above average next year is unlikely to influence overall cropping decisions, whereas a medium-term warning of a wet autumn might speed up root-harvesting.

16. Year-to-year variations in climate affect yield and agricultural technology needs to develop means of reducing the effects of this variability. The main climatic factor determining agricultural production is likely to continue to be the level and distribution of annual rainfall. A soil moisture deficit limits crop growth for periods in most years, and soil moisture *per se* has a dominant effect on the timeliness of cultivating, sowing and harvesting operations, and through these on yields at harvest. This is most evident on the heavier soils, for example in the Midlands, where more drainage is still needed to improve the flexibility of field operations. Rainfall, and associated humidity, also

interact with other factors such as plant and animal disease levels, crop pests and the efficiency of forage conservation. But overall the main effect of rainfall varying between years appears to be in the reduction of crop yields in years of moisture deficit. This suggests that increased irrigation of agricultural land would be needed, in particular in the South and East of England, and for the more drought sensitive crops—potatoes, field vegetables, sugar beet, and grass and forage crops. With a greater urban demand for water, a big increase in abstraction of deep water for irrigation is unlikely, and more reliance would have to be placed on impounding winter rainfall, linked with better information on optimum irrigation regimes, and on the automatic control of equipment.

17. In addition to the possible effects of climatic variability, it may be considered desirable to assess the effects of a trend in climate over the period to AD 2000. Although there is little evidence for any such trend, the remainder of this section of the paper considers the possible implications of one particular example of a climatic trend, that of a decrease in mean annual temperature of 1°C, to a climate similar to the "Little Ice Age" of the 16th and 17th centuries. A critical factor would be whether there was any between-season variation within this drop in mean temperature—a marked drop in winter temperatures but with no fall in Spring or Summer would have far less effect than a fall in Summer temperature. However, if a general drop of 1°C in mean temperature in all four seasons is assumed, some possible effects are:

(a) As the *number of growing days* is largely determined by soil temperature, it is estimated that the growing season would be reduced by about 30 days in the South and 20 days in the North and uplands. This would have a greater effect on spring-sown than on winter cereals, and would make autumn-sowing conditions more critical; reduce the scope for growing temperature-dependent crops such as potatoes and sugar beet; increase the risk of frost damage to fruit crops; and increase the indoor winter feeding period for livestock, so increasing both the dependence on conserved forages and the sensitivity to soil-moisture deficit in the main May/June growth period. Without many years advance warning, there would not be time to breed new adapted crop varieties, and reliance would have to be placed on growing varieties of cereals, roots and forages already adapted to a shorter growing season, particularly those used in some other countries. But overall crop yields per hectare would almost inevitably decrease from present levels unless changes in rainfall patterns modified markedly the effects of decreased temperature.

(b) Soil management. A decrease in mean temperature would decrease water evaporation and, unless accompanied by a corresponding decrease in rainfall, would reduce the land capability of large areas of the UK, in particular on clay soils. The resulting decrease in the days on which operations such as cultivation and sowing could be carried out—when in fact they would need to be more timely because of the shorter growing season—would further reduce crop potential. The more serious effect would be a reduction in the time available for harvesting potato and beet crops, and a need for the earlier housing of livestock. This reduced flexibility could well lead to

an increased level of mechanisation so that the required field operations could still be carried out and more field drainage would certainly be needed in many areas.

(c) Pests and diseases. The pattern and incidence of pests and diseases would almost certainly change, reflecting the dynamic nature of the initial inoculation, the build-up period of the pest or disease and the environments for re-infection, and the effects of lower temperatures on overwintering of specific infections. Again associated summer rainfall would have a dominant effect, with drought encouraging some insect pests, and high humidity some fungal infections. Incidence would also depend on new cropping patterns which might result from the shortened growing season. But there is no basis on which to predict any *overall* change in the incidence of pests and diseases.

(d) Livestock. More cattle and sheep would be housed, and for longer periods, as a result of the colder winters and shorter growing season, and a higher proportion of the grass and forage grown would be conserved before feeding: the effect on stocking rates would depend on the extent to which the climatic change not only reduced the overall growing season, but also reduced total grass production. Greater use would be made of materials at present wasted, in particular straw and vegetable residues, in ruminant feeding. Losses of livestock in severe winters such as 1977/78 might be reduced because few animals would remain outdoors in winter. Pigs and poultry are already largely isolated from the environment, but better insulation of buildings might be needed.

(e) Increased snow cover in winter would be likely, and would discourage outwintering of stock. It might also affect the crops grown, in particular the grass species; ryegrass, the main grass now sown in UK, is less resistant to winter freezing and snow cover than species such as cocksfoot and timothy, grown in Central Europe, which however give a lower yield of nutrients per hectare.

(f) The glasshouse sector of the *horticultural* industry would be part of the industry most affected by a fall in temperature. Calculations based on data from meteorological stations at Cranwell and at Cockle Park (mean temperature 1°C lower) show an 18 per cent increase in fuel use to maintain the same mean house temperature; on a national basis this would represent an increase in fuel costs at present prices of £7m on a protected crop output valued at £125m. If associated with a larger increase in the unit cost of fuel, it would lead to changes in crops and cropping patterns, some re-appraisal of the siting of the glasshouse industry, and greater investment in such items as controlled heating regimes and thermal screens.

18. The effects of any climatic change, such as a decrease in mean annual temperature of 1°C, could therefore be considerable. But the UK would be unlikely to be affected in isolation, by any change, for it would probably be part of a global trend which would reduce agricultural potential in many areas, and possibly increase the potential in others. Faced with a less favourable climate, the wealthier nations which are at present mainly concentrated in the temperate areas, would probably adapt their agricultural production systems

rapidly enough to overcome many of the damaging effects of the shift in climate. There would probably be particular problems in the tropics, the area which is already subject to the greatest climatic instability and where the major increases in population are now occurring. The effect of a drop in temperature in the UK could be trivial compared with the associated and unpredictable changes in the climate of other regions.

III. Possible effects of substantial increases in energy costs

19. In preparing its original paper submitted to the Royal Commission the Ministry assumed that the real price of oil might increase 'by a factor of two or more' by the end of the century. This is still the best central estimate available to us. Given that basic trends in the industry do not appear to have been altered dramatically by the real price rises in the first half of this decade, the probability remains that an increase of the order envisaged in the Ministry's original paper, or even a somewhat large increase, would not affect significantly the general picture outlined in that paper. However, in response to the Royal Commission's request, this section considers the possible effects on agriculture in the next 20 or 25 years of a much larger increase in oil prices.

20. There is no reason to expect a substantial increase in the real price of energy in the immediate future. If a major shift were to occur, it would be more likely to be towards the end of the century. If a very large increase were to occur, it would be most likely to be manifest first in the price of oil. It is by no means clear whether any such increase would be sudden or gradual; or how much it would affect the prices of other forms of energy (although some effect is to be expected). Nor is it clear how Government would react to such a change in its approach to the prices charged by the public corporations which supply much of the nation's energy; or in its policies on taxation. It should be noted that the existing oil tax structure is differential in its effects; the existing rebate of duty on fuel oil used in agriculture is but one example. And it is not to be excluded that, in the face of a substantial increase in energy costs, particularly if it emerged relatively quickly, Government might choose, at least in the short-term, to use tax and price measures to moderate its effects for uses, such as agriculture, which were considered essential. There might, therefore, be a significant time-lag before the full effects of a substantial rise in energy prices worked through to agriculture and food.

21. Any shift in real energy prices would almost certainly affect farmers throughout the world, although the effect would vary between countries and between producers depending on the nature of the price shift and the varying extent to which other factors, such as labour, could be substituted for the energy intensive inputs whose price would rise. If only agriculture were affected, one would expect that such an increase in the prices of important inputs would lead to a rise in output prices in real terms and a reduction in the demand for food but the effects on other industries (and their prices) of such a rise in energy costs would modify this effect significantly. The implications of the world-wide effects on UK production would depend on factors such as the relationship between changes in input costs and output prices both in the

UK and elsewhere, the ability of UK producers to minimize their costs for a given level of output relative to producers elsewhere and the overall effect of any actions taken by Government, alone or in international bodies, to moderate the impact of the price rise on agriculture and food. There could also be effects on the level of food consumption in the UK although it is difficult to forecast their likely direction and nature.

22. A number of estimates have been made of the proportion of the nation's total current energy usage which goes into the production, processing, distribution and consumption of food. The estimates differ in detail; but the broad picture can be illustrated by one example which suggests that the feeding of the UK's population involves an expenditure of about 16 per cent of the total primary energy use in the UK to cover the many activities that take place before food is available for consumption on the plate. The breakdown of this energy use may be expressed as agriculture (to the farm gate) (3·9 per cent), processing, packaging and distribution (7·0 per cent) and food storage and preparation (4·9 per cent). Thus it can be seen that the additional energy used down stream of agriculture, in processing, distribution and in the home, is probably three times larger than the energy used to make produce available at the farm gate. Of the energy using inputs into agriculture a major item is petroleum fuel at 24 per cent with fertilizers (principally, nitrogenous fertilizers using gas as a feedstock) coming a close second at 23 per cent. Other major users of energy include the manufacture of machinery (14 per cent), off-farm feedstuff processing (14 per cent) and electricity (9·2 per cent). In one specialised sector, glasshouse horticulture, energy for heating, mostly oil, is of considerable importance and accounts for no less than 25 per cent of agriculture's petroleum fuel use.

23. On this basis some broad indications of the likely effects of a sharp rise in energy prices can be deduced, although many of the detailed effects would depend upon the phasing of the price change between the various energy sources and the way in which their impact was felt. The degree to which there is scope for energy saving in home cooking and food preservation—except perhaps in reducing wastage—is difficult to assess. For example, whilst freezers use energy, their use may reduce the amount of fuel used in food distribution; and whilst convenience foods may save household energy, their manufacture consumes energy. A substantial increase in energy prices could, for example, intensify the trend away from cooked breakfasts; it might lead to a more general trend towards foods which require little or no cooking; and it might lead to an increased emphasis on energy-efficiency in household food preparation, perhaps with the use of different cooking techniques including microwave ovens. However, it is by no means clear what effects changes in the household and in the food processing industry would have on the demand for food and, hence, on the agriculture industry.

24. A substantial increase in energy prices could be expected, however, to have implications for food distribution which could have an impact on agricultural production patterns. If, as might be expected, distributive costs,

especially for road transport, rose sharply, there might be a tendency to seek means of reducing them, provided that the investment resources needed, including those of energy, were available, by developing the use of less energy-intensive distribution systems, and by locating the different agricultural processes closer to the major consuming areas. The latter might result in a shift, reversing recent trends, towards mixed farming patterns. A return to mixed farming would also have the advantages that a higher proportion of livestock feeds could be produced close to the livestock, so reducing the energy costs of transporting and processing feed; and that better use of animal wastes could reduce fertilizer requirements.

25. On the farm, the effects of a substantial rise in energy prices would be felt primarily in the cost of fuel for farm operations, the cost of machinery (much of which also consumes fuel) and the cost of nitrogen fertilizer. As a result a greater stress on machinery efficiency and a reduction in the amount of machinery power held in reserve to meet unusual conditions could be expected. But it is difficult to assess where the balance between the various effects would fall. It is by no means clear how large an increase in energy prices would be needed to reverse the trend towards machinery-intensive systems. If there were to be any shift towards labour-intensive systems, its scale and nature would be influenced strongly by the state of employment in the economy as a whole, itself affected by the energy price rise, and by location and skills of whatever labour was available.

26. Some of the effects on agriculture of higher energy prices could be moderated by technological developments, or the increased application of existing technology, which would then become economic. The use of coal-based steam or electric power or liquid fuels derived from coal might offset some of the effects of a high oil price. But, on the other hand, a sharp increase in oil prices would lead to increased demand for coal mining with possible implications for losses of agricultural land. It is also possible that novel energy sources such as straw burning, methane production from animal waste, wind and solar energy would tend to become more viable economically. Waste heat recovery from power stations and industry could be a possible source of energy to the heated glasshouse sector of the horticultural industry which would be the sector most severely hit by a steep rise in energy prices.

IV. Other possible developments

27. If the UK needed to increase domestic production, an increase in fertilizer usage would be needed; this would mainly be on grass and forage crops with much lower increases on arable crops. In both cases the largest increase would be of nitrogen with phosphate and potash dressings being applied according to the needs of the soil. The cost of inorganic fertilizers means that economic pressures would continue to require that the maximum use be made of organic residues: but if it were necessary to approach self-sufficiency in temperate food substantial additional quantities of inorganic fertilizers could be needed.

28. The question of resistance to pesticides is considered in detail elsewhere in the Ministry's supplementary evidence. If resistance developed it would probably do so at different rates for different pests, and, hence, would have differential effects between crops. It is not, however, possible, to forecast over twenty or more years where, and to what degree, pesticide resistance may be a problem, or the extent to which improved knowledge (including developments in plant breeding) would enable us to develop an effective strategy to combat its effects. But although resistance problems with some categories of pesticides (eg insecticides) are likely to increase, we would not expect them to be a major constraint on agricultural production by the end of the century.

29. A number of possible technical developments were mentioned in the Ministry's earlier paper. Whether, and to what extent, they are adopted will depend on factors such as the degree of pressure for increased production, the level of general economic activity and the nature of constraints external to the industry proper (such as environmental legislation, taxation arrangements and any changes in land tenure patterns). To the extent that any increased production were both desired and the need for it reflected in improved returns, the rate at which technical progress is taken up will tend to increase. But of relevance also is the individual decision-maker, and it is not easy to guess what the overall effect of a large number of individual decisions will be. In its original paper the Ministry argued that pressures on world food production might increase, without becoming critical. The following points on possible developments are made on the same basis.

30. Of obvious potential significance would be *techniques to reduce energy use* (see also paragraph 26 above). They might be adopted not from a specific need to save energy, but because "energy" represents a high proportion of the inputs into agricultural production, so that saving energy is an effective way of restraining costs. In this sense many techniques for increasing productivity will increase the efficiency with which overall energy inputs are used: for example, crop protection, where the increased yield of crop can far outweigh the energy needed to make and distribute a pesticide; forage conservation, with small additions of chemicals greatly reducing storage losses; and animal disease control and improved reproductive performance, both of which increase food output per unit of feed eaten.

31. It is estimated that *minimum cultivation techniques* may already be used on nearly 0·4 million ha and their use is likely to spread. Such techniques can reduce the direct energy needed to plant a cereal crop by up to 50 per cent—an energy saving which is only partially offset by the energy used in making the necessary chemicals—and also make the operation less sensitive to bad weather than conventional cultivations. At present these techniques are most effective on the lighter soils—they could become much more widely used. When minimum cultivation is applied over a period of years soil structure appears to improve at any rate on certain soils. Such systems might be the main method of establishing cereal and forage crops by the end of the century.

32. As paragraph 22 above has mentioned, nitrogen fertilizers represent a major energy input into agricultural systems: to date UK agriculture has been partly shielded from the true costs of nitrogen by the relatively low price which, until recently, ICI paid for its natural gas feedstock. But prices are now tending to increase towards those obtainable elsewhere in the world. If so, farmers may tend to use nitrogen fertilizers more sparingly, especially on grassland, to ensure better recycling of the nitrogen in animal manures, and to grow more legumes, which fix atmospheric nitrogen. Hence the interest in the possibility of introducing *nitrogen-fixing* genes into non-leguminous crops such as cereals and grasses. But while experts in this subject believe it can be achieved, they expect it to take some 10–20 years, so that the new crops are unlikely to have much importance before the end of the century. There is also the underlying concern that however nitrogen is fixed a high energy output is needed; in nitrogen-fixing crops this comes from the photosynthetic pool, and this could reduce the energy-yielding potential of the crop. Clearly this is a subject for long-term, fundamental research; an attempt is now being made to get co-ordination of the research activity within several OECD countries aimed at more rapid progress in the study of nitrogen fixation.

33. Recent work has demonstrated the great variation in the uniformity of distribution of agricultural chemicals by existing spraying equipment: as a result level of usage tends to be much higher than the theoretical optimum, to ensure adequate disease or pest control on plants getting a low spray rate. Most sprayers also give a larger-than-optimum droplet size which reduces chemical efficiency. Machines designed to give much more uniform spray application, coupled with smaller droplet size, should markedly reduce the amounts of chemicals applied. Indeed, this is already happening and the trend will probably be stimulated by the likely increase in unit cost of chemicals resulting from higher costs of production and safety testing, so as to become the common method of application well before the end of the century. In the field of chemicals, it should, moreover be noted that the last two decades have seen major developments. Within that period we have witnessed the development from the marketing of the first selective herbicide for wild oats to the present situation in which a very wide range of extremely selective materials are available, some able to control particular grass species within a mixed sward. In that light it would not be surprising, for example, if by the end of the century long-term fungicides were available which could be applied to seed, with consequential implications for the scale and nature of chemical applications in the field.

34. The increasing value of the plant nutrients in animal wastes has already been noted. Over the coming years, much greater attention will probably be given to the storage and distribution of animal wastes both because over half the nitrogen content of manure can be lost during inefficient storage and because, as farmers become more aware of the fertilizer value of their manures, there will be greater concern to avoid run-off to watercourses and odour pollution. There will also be greater interest in the recycling of manures as animal feed, probably with fairly complex methods of intermediate

processing to ensure adequate hygiene and to minimize consumer concern. The extent to which recycling as feed is adopted will depend largely on the supply and price of conventional animal feedstuffs, particularly proteins: it will seldom be adopted primarily as a method of waste disposal, except possibly in intensive pig units close to urban areas.

35. Paragraphs 30 to 34 have discussed in rather more detail some of the possible developments in farming techniques mentioned in the Ministry's original paper which appear to be of particular interest to the Royal Commission. It should be noted, however, that others, such as improved breeding and rearing methods for livestock and changes in food consumption patterns, could have as much or more impact.

APPENDIX 7

Sources of nitrate in the diet: construction of Table 4.3b

1. Table 6 of the "Survey of Household Food Consumption and Expenditure 1976"[1] gives basic information on the weekly consumption of various types of food in the home. The survey excludes food purchased and consumed outside the home (lunches at work etc) but this amounts to less than 10 per cent of total consumption and its exclusion should not significantly alter the pattern of consumption. In the survey, data are expressed in imperial measures; these are converted to metric units with some rounding off.

2. There are certain foodstuffs to which nitrate is added as a preservative and there are others in which nitrate occurs naturally. Data are available for the following groups.

(a) Meat products. The term includes ham, bacon, luncheon meat, corned beef, certain types of sausage and similar products. At the time of writing, UK regulations permit a maximum of 500mg sodium nitrate/kg of product. This corresponds to 350mg NO_3/kg. In practice, much lower concentrations are found. Data supplied by the secretariat of the Steering Group on Food Surveillance show a mean value close to 100mg NO_3/kg for canned cured meats (including ham) and speciality sausages. We are advised by BFMIRA that for bacon and ham, 150mg NO_3/kg would be "a high figure". For this group of foodstuffs, therefore, a concentration of 100mg NO_3/kg is assumed.

(b) Milk. This includes whole, dried, concentrated and evaporated milk. Data supplied by the Steering Group suggests that 30mg NO_3/l is a reasonable figure. Quantities of processed milks are expressed as the equivalent volume of whole milk.

(c) Cheese. Certain types of cheese are permitted to contain nitrate preservative. Data supplied by the Steering Group indicate a mean value of about 45mg NO_3/kg for a range of cheeses.

(d) Vegetables. The nitrate content of vegetables varies widely. The pattern of variation is the same for fresh and processed vegetables and they are grouped together. BFMIRA suggest 200mg NO_3/kg as the likely nitrate content of a typical mixed vegetable diet.

(e) Potatoes. BFMIRA advise that the nitrate content of a modern potato is subject to wide variation and that 60mg NO_3/kg would be "the upper end of the range" but not uncommon. This figure is taken. Uncooked and processed potatoes are grouped together. Processed potato (over half of which is frozen chips or chips from a chip shop) accounts for only 7 per cent of potato consumption.

3. The figure for consumption of water is taken from a survey of total fluid intake of adults.[2] It includes water consumed straight from the tap and water used in the making of tea and coffee.

4. Using this information, Table 4.3b was constructed. Numbers are rounded. It must be noted that there are other major groups of foodstuffs for which data are not readily available (but which are likely to be low in nitrate content). These are listed below; it will be seen that the list includes the largest single group, cereal products.

	Weekly intake (g)
Cereal products	1630
Fats	310
Fish	130
Fresh meat and offal	620
Sugar and preserves	410

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