TOXIC CHEMICALS IN AGRICULTURE AND FOOD STORAGE

REPORT OF THE RESEARCH STUDY GROUP
ON TOXIC CHEMICALS IN AGRICULTURE
AND FOOD STORAGE
to the Minister of Agriculture, Fisheries and Food,
the Minister for Science,
the Secretary of State for Scotland
and the Minister of Health

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I. INTRODUCTION

1. The use of chemicals to control pests of crops and animals is long-established. It has now become an integral part of good husbandry, not a substitute for it. Under modern conditions the safeguarding of the farmer's crops and livestock at their present level of production, and the feeding of the increasing population, depend on the use of chemicals.

2. Before World War II, except for some organo-mercury seed dressings and tar oil washes for fruit trees, the pesticides available consisted, in the main, of a very limited number of inorganic products and a few insecticides of natural origin. In the last twenty years, however, advances in synthetic organic chemistry have produced almost as wide a range of new chemicals for crop protection as of drugs in the field of human medicine. These pesticides have been characterised by increased and sometimes more specific biological activity. It is not surprising that new problems of safe and efficient handling and application, depending on the mammalian and avian toxicity of the chemicals, have arisen. The rapidity of advance in the science of crop protection, and its increasing complexity, have emphasised the importance of studying the effects and methods of use of new pesticides more intensively.

3. The consequences of the increased use of toxic substances in agriculture were comprehensively studied by the Zuckerman Working Party which reported to Ministers in 1951, 1953 and 1955. The reports dealt with the safety of workers handling toxic or harmful chemicals in agriculture (First Report), with possible risks to consumers from the use of such chemicals on agricultural and stored products (Second Report), and with possible risks to the natural flora and fauna of the countryside (Third Report). Their main recommendations were put into effect by legislation and by the creation of a voluntary Notification Scheme, which imposes heavy demands on industry for information on all new pesticides. Nevertheless, many members of the public still believe that new and dangerous pesticides are indiscriminately introduced and applied to food crops, with little knowledge of the harm or good they may do, and without adequate testing. We were surprised to find, from some of the evidence submitted to us, that much ignorance prevails as to existing legislation and control measures in the United Kingdom, particularly in regard to the Notification Scheme. We, therefore, discuss these measures in some detail later in this Report.

4. Undoubtedly some public uneasiness exists about the use of chemicals in agriculture. We believe this to be of four main kinds, concerning

(*a*) risks to man and domestic animals from the handling and application of poisonous chemicals;
(*b*) effects of pesticide residues in food;
(*c*) risks to wild life; and
(*d*) possible disturbance of the 'balance of nature'.

5. Risks from the handling of poisonous chemicals became evident when the dinitro herbicides and organo-phosphorus insecticides were introduced after the 1939–45 War and fatalities to man and livestock were first reported. Deaths of

cattle increased when alkali arsenites began to be used for potato haulm killing, and in 1959 a human fatality resulted from the accidental contamination of a domestic water supply by these substances.

6. Anxiety about residues of pesticides in food cannot be traced to specific causes, but much of it appears to have arisen as a result of articles in the press, referring to 'poison sprays' and 'poison in your food'. Often implied in these articles is the idea that traces of certain pesticides might have harmful effects if ingested in foodstuffs over long periods.

7. Anxiety about risks to wild life developed when a dinitro and an organophosphorus compound were shown to have caused the deaths of a considerable number of birds and other wild creatures after the spraying of farm crops in the early 1950's. It has increased greatly in the last two years, when reports have appeared of widespread deaths of birds and other forms of wild life, now traced to the use of certain seed dressings.

8. Finally, apprehension has often been expressed about the effects of toxic chemicals on the 'balance of nature'. This expression, though popularly used, is difficult to define. Any such 'balance' which may exist is certainly not static. Human activity necessarily affects the relative populations of wild species and it cannot be assumed that the resultant changes are always deleterious.

9. All these matters have received widespread publicity and it was to review the whole question and to make recommendations for any further research needed, that this Group was appointed.

II. TERMS OF REFERENCE: DEFINITIONS

10. We were appointed in February, 1960, as a Research Study Group, by the Minister of Agriculture, Fisheries and Food, the Minister for Science, the Secretary of State for Scotland and the Minister of Health, with the following terms of reference:

> 'To study the need for further research into the effects of the use of toxic chemicals in agriculture and food storage, and to make recommendations.'

11. For the purpose of our work, we defined 'toxic chemical' as any pesticide, that is, insecticide, fungicide, herbicide, rodenticide or similar chemical, used in agriculture (including horticulture) and food storage. Apparently harmless chemicals may be toxic in certain circumstances. We did not regard our terms of reference as including oestrogens, antibiotics or chemicals deliberately added to human or animal food, as these are under study by other official committees. Throughout this Report we have interpreted 'research' in the broadest sense and have taken it to include, as well as fundamental research, the application of results of fundamental research to practical agricultural problems, the devising and testing of experimental and analytical techniques, and the collection of statistical information by censuses and surveys.

12. Our terms of reference do not include consideration of administrative and legislative aspects of the control of toxic chemicals, but we have had to take note of any such proposals put before us in evidence, and have passed them to the appropriate Government Departments. In our deliberations we have frequently found it necessary to go into the administrative and legislative field and, indeed, in this Report we discuss some of these matters.

III. EVIDENCE RECEIVED

13. We issued a press notice in April, 1960, inviting those with information on the subject to send details to the Secretariat. The response was negligible.

14. We next invited evidence from bodies and individuals concerned with the manufacture, sale, use or effects of pesticides in agriculture and food storage who, we felt, could assist our enquiry. They included organisations of chemical manufacturers, of merchants, and of farmers, trade unions, food manufacturing and research associations, scientific societies, medical associations, and bodies concerned with natural history, game preservation and field sports. Sixteen organisations submitted written evidence and supplemented this by oral evidence from their representatives; 12 submitted written evidence only and 13 had no collective views to offer or had their views covered by the evidence of associated bodies. We also approached a number of research workers in Government Departments, research stations and universities, who were known to be working in fields relevant to the Group's enquiry, and invited them to inform us of what they had done, and were doing, in these fields and what, in their view, remained to be done. We received statements or information from 28 such workers. We desire to express our thanks to the organisations and individuals who submitted evidence to us and prepared detailed statements of their views. Lists of those who provided evidence are given in Appendix A.

15. We obtained details of relevant work done by the Medical Research Council, the Agricultural Research Council, the Department of Scientific and Industrial Research, the Nature Conservancy, other research centres, and industrial laboratories.

16. We made use of the very extensive literature on the subject published at home and abroad, including papers prepared by other committees dealing with subjects related to our field of enquiry. We did not conceive it our duty to summarise, in this Report, all the evidence we received or the literature we consulted.

IV. THE CHEMICALS USED

17. We prepared a list (Appendix B) of pesticides used in the United Kingdom. This brings up-to-date the list of crop-protecting chemicals printed in the Second Report of the Zuckerman Working Party. All are stated to be commercially

available in the United Kingdom, but some are intended for minor, specialised purposes, and are very little used. Our list indicates, for any pesticide, its chemical group, its primary use, whether products containing it have been approved, whether its use is controlled under the Agriculture (Poisonous Substances) Regulations, and whether official recommendations for its safe use have been issued. (Descriptions of the two voluntary schemes under which pesticide products are approved and official recommendations for their safe use issued, and of the Regulations, are given later in this Report.) Any assessment of the hazard presented by a pesticide to users, consumers and wild life must be based on the consideration of quite a number of factors. Commonly, lists claiming to show the order of toxicity of pesticides are based on only one factor, such as oral toxicity to laboratory animals. We have refrained from listing chemicals in this way.

18. Of the 153 chemicals in the list (the several copper and organo-mercury compounds used as fungicides are each regarded as one), only 20 are regulated; a further 5, named in the Regulations, have been withdrawn from commercial use and are, therefore, not included in our list. Official recommendations on safe use have been issued for 47 chemicals. These include most of the regulated chemicals, but also some relatively non-toxic ones which have been notified. All pesticides which are on the market are subject to review by the appropriate committees, following which official recommendations on safe use are issued. Some 70 of the chemicals, which have been on the market for some time and for which no official recommendations have yet been issued, are, in our opinion, relatively harmless and present no significant hazard under proper conditions of use.

V. THE NEED FOR PESTICIDES AND THE EXTENT OF THEIR USE

19. The losses of food from the depredations of pests and diseases amount to many millions of pounds sterling for this country alone. Ordish[1] estimated that in 1947, when particularly severe attacks occurred, the loss from pests and diseases of growing crops in the United Kingdom was of the order of £78 million, even after nearly £10 million had been spent on control measures. Others considered this figure might be as large as £140 million, if due allowance were made for the effects of weeds and for losses from rodents and in storage.

20. We have obtained more precise information on the loss in yield caused by certain economic pests and diseases when pesticides are not used, as well as data about the extent of use of a few chemicals, from the surveys and assessments made by the Plant Pathology Laboratory and the National Agricultural Advisory Service. A comprehensive review is outside the scope of this Report, but we have thought it desirable to give some illustrative examples. More spectacular ones could be quoted from other countries, where immense acreages are often devoted to a single crop.

[1] G. Ordish, *Untaken Harvest*, 1952, p. 34.

21. The surveys have shown that over a 10-year period 14 per cent of the total production of brussels sprouts in this country was lost through aphid damage. Over a 12-year period losses of oats from frit fly attack amounted to 16 per cent of the total yield.

22. During the years 1947–56 the average annual loss of potatoes in England and Wales from potato blight was estimated to be 11·6 per cent of the potential yield of second early and main crop varieties, or about 500,000 tons. Wireworm, slug and cutworm attacks alone represented a loss of about 8,300 acres out of the average annual acreage of 550,000. The mean percentage of ware potato fields treated with insecticides during 1955–60 was 20·7 for England and Wales and 0·6 for Scotland. Practically all the treatments were with aldrin and dieldrin for wireworm control. The amount of potato spraying with fungicides varies from year to year. In 1960 about half the maincrop potatoes in England and Wales were protectively sprayed or dusted against potato blight. About two-thirds of the spraying or dusting was done with copper preparations and the rest with dithiocarbamates (such as zineb). Destruction of potato haulm, mostly by spraying, to facilitate lifting and to reduce tuber infection by blight, also varies in amount from year to year. From 1957 to 1960 the total acreage in Great Britain so treated ranged from 245,000 to 350,000, of which from 76,000 to 154,000 were burnt off with the alkali arsenites. Regular spraying with copper fungicides against potato blight in Northern Ireland gives an increased crop yield of approximately 30 hundredweights per acre in a normal season.

23. Similar assessments for sugar beet have been made for Great Britain by the British Sugar Corporation, in conjunction with the Rothamsted Experimental Station. During the 12-year period 1946–57 over 7 per cent of the crop was lost through attacks of virus yellows. Sugar beet, of which there are over 400,000 acres in Great Britain, is sprayed with organo-phosphorus insecticides to control the aphid vector of this disease. Up to 1956 there was only pilot scale spraying. In 1957 there was a very severe attack of virus yellows and about 100,000 acres were sprayed. In 1959 another severe attack was forecast: the area sprayed rose to 381,000 acres and it was reliably estimated that, but for spraying, only $4\frac{1}{2}$ million instead of $5\frac{1}{2}$ million tons of roots would have been harvested that year. In 1960 210,000 acres were sprayed with organo-phosphorus insecticides.

24. There is no question of the value and importance of fungicidal seed dressings to agriculture. They are an insurance against loss due to a number of seed-borne organisms and it is essential to treat seed annually or periodically, if a heavy and serious build-up of diseases is to be avoided. Some seed-borne diseases, which at one time caused very serious losses of wheat, oats and barley, have now ceased to be of consequence. During the inter-war period it was estimated that the treatment of seed oats with an effective organo-mercury dressing produced in Northern Ireland an increased grain yield of 7 per cent. It is difficult to obtain precise and up-to-date figures of the extent of use of seed dressings. The total cereal acreage in Great Britain was about 7 million in 1958, and of this, three-quarters or more of the wheat and at least one half of the oats and barley are estimated to have been treated with seed dressings.

25. The effectiveness of seed dressing was greatly increased when dual-purpose dressings were introduced, incorporating insecticides with the fungicides. It then became possible to protect the crops not only against seed-borne diseases, but also against insect pests. The most important of these insect pests are wireworm

and wheat bulb fly. In certain circumstances wireworms may lead to a complete loss of a cereal crop and in 1953, before dual-purpose dressings were introduced, wheat bulb fly caused a total loss of about £1¼ million, a figure which is now very much reduced. The first insecticide to be used in dual-purpose seed dressings was BHC, which was very effective against insect pests in the soil, but which sometimes had a damaging effect on seedlings. Largely for this reason there was a trend in recent years for it to be replaced by aldrin, dieldrin and heptachlor, until the harmful effects of these chemicals on birds became apparent. As a result of the agreement reached between the Ministry of Agriculture, Fisheries and Food and various organisations in June 1961, that these dressings shall no longer be used (except for the control of wheat bulb fly in autumn-sown wheat), it is likely that BHC dressings will be used again in dressings for spring-sown corn.

26. By far the greatest use of herbicides in agriculture is on cereal crops, of which about 60 per cent were sprayed in Great Britain in 1959. Of the sprayed acreage nine-tenths or more were sprayed with herbicides of the growth regulator type (the so-called 'hormone weedkillers'), which do not present a toxic hazard to man or animals. About 20 per cent of the acreage of brussels sprouts, kale, swedes, turnips, mangolds, peas, potatoes and sugar beet (which, taken together, represent one-twentieth of our cropping areas) appear at present to be treated annually with pesticides, while 60–85 per cent of the fruit and hops (taking up one-hundredth of our productive land) are treated as a matter of routine with a variety of sprays.

27. No figures exist to show the total amount of pesticides used in this country. It was clear to us that information on this matter could only be obtained from the makers and formulators (including importers), who are understandably reluctant to disclose commercially confidential information. With the co-operation of the Association of British Manufacturers of Agricultural Chemicals and its member firms, figures were assembled showing the sales, for use in the United Kingdom, of those pesticides considered sufficiently toxic to be regulated. The first category below embraces 17 of the substances included in Part I and Part II of the Second Schedule of the Agriculture (Poisonous Substances) Regulations—that is, the more toxic chemicals (see Appendix D)—while the second category covers three chemicals which are less hazardous and therefore included in Part III of the Schedule. The chemicals involved are:

CATEGORY 1: amiton, demeton, dimefox, dinoseb, DNOC, endothal, endrin, fluoroacetamide, mazidox, mipafox, mevinphos, parathion, potassium arsenite, schradan, sodium arsenite, sulfotep, TEPP.

CATEGORY 2: azinphos-methyl, demeton-methyl, phosphamidon.

All firms approached provided the information requested and full co-operation prevented duplication of the amounts sold. The following figures show (in thousands of acres) the 'acres sprayed' in the United Kingdom, but the actual acreage is less, as some areas were sprayed more than once. It may be noted that the total area under edible crops in June, 1960, was 10,952 thousands of acres.

Year	*Category 1*	*Category 2*	*Total*
1955	436	17	453
1960	330	593	923

28. The low figure in the second category, for 1955, is due to the fact that these less toxic chemicals had not been generally introduced by that year. The enquiry has shown that the acreage sprayed with all these chemicals has more than doubled in the five-year period, but that the acreage for the more toxic ones has declined by a quarter. The alkali arsenites are included in the first category, and their withdrawal from use after 1960 will mean a further substantial reduction in the acreage treated with chemicals in this category.

29. The above figures show that in the five-year period 1955–1960 there was considerable progress in replacing the more toxic by less toxic spray materials. This is a very desirable trend.

VI. PRESENT MEASURES FOR CONTROLLING THE SALE AND USE OF PESTICIDES

30. It seemed to us essential to consider the current measures for the control of the sale and use of pesticides in Great Britain. As they appeared to be very inadequately known to many of those who gave evidence, we summarise these measures below.

31. The measures consist of a number of Acts and two voluntary schemes. Similar Acts operate in Northern Ireland, which also participates in the Agricultural Chemicals Approval Scheme.

(i) *Pharmacy and Poisons Act, 1933, and Regulations made thereunder*

Toxic chemicals used in agriculture are covered by these regulations. It is compulsory to state on labels of products containing scheduled poisons, in a prescribed form, the name and content of the active toxic agent. The regulations lay down certain labelling requirements, including prescribed warning notices; they also place restrictions on the sale of products containing scheduled poisons. Thus users of the more toxic chemicals, who may know proprietary pesticides containing such chemicals only by their trade names, can learn from the label what the active toxic agent is. Industry, by agreement, also usually states on the label whether the use of the product is subject to the Agriculture (Poisonous Substances) Regulations (see below).

(ii) *Food and Drugs Acts, 1955, Food and Drugs Act (Scotland), 1956, and Regulations made thereunder* (see also Appendix C)

The Food and Drugs Acts have at present limited application to the use of pesticides in agriculture, but contain powers (Section 4) under which regulations can be made setting upper limits for residues in foods or prohibiting the presence of a particular residue or class of residue.

(iii) *Hydrogen Cyanide (Fumigation) Act, 1937*

This Act enables the Secretary of State (Home Office) to make regulations to protect persons from danger in connexion with the use of hydrogen cyanide or (by Order in Council, under Section 4) with the use of any other fumigant.

Regulations under the Act at present apply respectively to fumigations in buildings and to fumigations in ships with hydrogen cyanide. The precautions required include the use of trained operatives; evacuation of people from premises; posting of warning notices before the start of operations; and testing for clearance of the fumigant at the conclusion. Permission to treat foodstuffs must be obtained from an officer of the Ministry of Agriculture, Fisheries and Food or, in certain instances, from the medical officer of health of the locality.

Although the power in Section 4 of the Act has not been used to extend the provisions of the Act to fumigation with other substances, advisory leaflets concerned with safety precautions have been issued in respect of the use of ethylene oxide and methyl bromide as fumigants.

(iv) *Agriculture (Poisonous Substances) Act, 1952, and Regulations made thereunder* (see also Appendix D)

This Act enables the Minister of Agriculture, Fisheries and Food, and the Secretary of State for Scotland to make regulations to protect workers using toxic chemicals in agriculture. The regulations made under the Act require certain precautions, including the wearing of appropriate protective clothing when workers are using specified chemicals. The Regulations are enforced in England and Wales by the Ministry of Agriculture, Fisheries and Food's Safety and Wages Inspectorate, which consists at present of a Chief Inspector, a Deputy Chief Inspector, eight Regional Inspectors and 62 Divisional Inspectors. In Scotland the Inspectorate consists of a Chief Inspector, two Deputy Chief Inspectors and nine Inspectors. Both Inspectorates are concerned also with the enforcement of the Agricultural Wages Act and the Agriculture (Safety, Health and Welfare Provisions) Act. The general impression from evidence given to us is that contractors and their employees abide by the regulations. Farmers who do the spraying themselves (but not their employees) are outside the regulations and are perhaps less careful. However, farmers and their employees normally spray only for relatively short periods and are, therefore, less exposed to risks than the employees of contractors.

Information on the regulations is provided in a number of Ministry leaflets, which give simple and clear guidance on the safe use of poisonous chemicals on the farm, and on the conditions that have to be complied with. The leaflets cover the whole field of the use of agricultural chemicals. We consider them excellent and deserving of the widest circulation. Certain of them have been distributed through the medium of the National Farmers' Union, the National Union of Agricultural Workers, and the Transport and General Workers' Union (Agricultural Section). The publications are listed in Appendix D.

(v) *The Notification of Pesticides Scheme* (see also Appendix E)

The voluntary Notification Scheme resulted from the Second Report of the Zuckerman Working Party, on possible hazards from residues in crops treated with agricultural chemicals, and from its Third Report, on risks to wild life.

The Scheme, agreed between the Government and industry, came into operation in 1957 and formalised the looser arrangements then being followed. It is described fully in the pamphlet 'The Notification of Pesticides Scheme agreed between Government and Industry'. Under the Scheme a manufacturer, when proposing to market a new chemical, or to introduce a new formulation or new use of a chemical already on the market, is expected to notify the Ministry of Agriculture, Fisheries and Food if his product might offer a hazard to users, to consumers of treated crops, to domestic animals or to wild life. Notification is

made before marketing and must be supported by adequate data on the composition of the product, its proposed method of use, mode of action, toxicity, persistence, any residues likely to result from its use, hazards to wild life, and other relevant information. Two official committees consider these data. The Advisory Committee on Poisonous Substances used in Agriculture and Food Storage is a committee of administrative and scientific representatives from official departments and organisations concerned with the use of pesticides, together with an independent chairman and five scientists drawn mainly from the universities. It has a Scientific Subcommittee, whose members are scientists selected for their expert knowledge of various aspects of pesticides. Industry is not represented on these committees, a fuller description of which is given in Appendix E.

The two committees make recommendations for the safe use of notified products and these recommendations are cleared with Government Departments and the notifiers before being published. They are available in collected form in a dossier entitled 'Chemical Compounds used in Agriculture and Food Storage in Great Britain: User and Consumer Safety: Advice of Government Departments'. A specimen dossier sheet is reproduced in Appendix E.

Under the Scheme, as it stands at present, manufacturers may use their discretion whether to notify but, having decided to notify, they accept the onus of providing all the data necessary to enable the committees to reach a decision.

Departments exercise vigilance in surveying the products on the market and can, if necessary, ask the committees to consider a product without waiting for it to be notified. No case has been brought to our notice of continued failure to notify a chemical which presented hazards and should have been notified. We understand, however, that consideration is being given to a proposal by industry that all new chemicals should be notified.

(vi) *The Agricultural Chemicals Approval Scheme* (see also Appendix F)

This voluntary Scheme deals with the biological efficiency of pesticides. It is linked to the Notification Scheme in that a product containing a toxic chemical cannot be granted approval unless it has first been cleared under the Notification Scheme. In spite of the considerable publicity given to the Approval Scheme by the Ministry of Agriculture, Fisheries and Food, it does not appear to be sufficiently known to farmers. Its potential usefulness to users of agricultural chemicals is such that we hope every opportunity will be taken to make it better known.

32. The criticism was made to us that voluntary schemes of control are inadequate. We have heard no evidence to cause us to conclude that the two schemes in question are failing in their purpose or that more could be achieved by compulsory measures. Both schemes are flexible and provide opportunities for joint consultation, sufficient to fulfil the desire of the Government and industry that the schemes should function with full efficiency.

VII. WHERE RELEVANT RESEARCH IS IN PROGRESS

33. We have surveyed the research in progress at various agricultural, medical and chemical research centres and have received evidence of the work that has

been, and is being, done. We have also received the views of research workers on what problems still required solution and what further work, in their opinion, should be done. The field of investigation is very large and this survey cannot be comprehensive, since it does not include all work being carried out in universities, in industry and elsewhere. We are satisfied that all major matters relevant to our enquiry are under investigation to some degree. The recommendations which we make later in this Report are therefore directed to the extension or intensification of this work.

34. Relevant research is undertaken by the following:

(i) *Agricultural Research Council*

Appendix G gives examples of the work in progress at research institutes and units and in university departments, grant-aided by the Agricultural Research Council. Most of the work is aimed at improving the efficacy of chemicals for the control of pests and diseases of plants and for the suppression of weeds. But it also involves studies of side-effects, such as effects on the populations of beneficial insects, on the soil fauna and flora, and on the development of resistant strains of pests. Fundamental studies on pesticide action and on application problems are also in progress, from which more efficient methods of control may be developed.

(ii) *Agricultural Departments*

The Plant Pathology Laboratory is concerned with agricultural chemicals in relation to the Notification Scheme and the Agricultural Chemicals Approval Scheme. It carries out research on the determination of pesticide residues in foodstuffs, analytical methods for agricultural chemicals and products, and application techniques, and has done work on the protective clothing required when certain toxic chemicals are used in the field.

The Infestation Control Laboratory is concerned with chemicals used against insects and mites in stored food, and against mammal and bird pests. Under the Notification Scheme it is responsible for products within these spheres of use. It is also concerned with investigations, including some chemical analytical work, into the hazards to wild birds and mammals from pesticides.

The Central Veterinary Laboratory investigates hazards to farm livestock arising from the use of pesticides, and deals with accidents or incidents brought to its notice.

The Salmon and Freshwater Fisheries Laboratory has developed a standard method for testing substances for toxicity to fish and has determined the toxicity of certain herbicides, algicides, fungicides and insecticides. It is also concerned with the effects of chemicals used for the control and treatment of water plants.

The Plant Pathology Section of the Scientific Services Station of the Department of Agriculture and Fisheries for Scotland deals with the effects of fungicides and insecticides on seeds, with fumigation of stored products and with insecticide residues on foodstuffs. The Department's Infestation and Rodent Control Sections and its Freshwater Fisheries Laboratory carry out investigations similar to those undertaken by the corresponding services in England and Wales.

The Plant Pathology and Agricultural Entomology Divisions of the Ministry of Agriculture for Northern Ireland are engaged in research problems concerned with the introduction and sale of new fungicides and insecticides. They are also responsible for determining the value of certain crop protection chemicals and have evolved techniques for the rapid and accurate assessment of the efficacy of fungicides, especially seed dressings.

(iii) *Department of Scientific and Industrial Research*

Research into the development of methods of analysis of pesticides, and of residues in foodstuffs, is carried out in the Laboratory of the Government Chemist, which also collaborates in residue determinations in connexion with experimental trials. Pesticide residue analysis is also carried out at the Tropical Products Institute.

The Department is also concerned in the creation of the new British Industrial Biological Research Association, which was incorporated in October, 1960, and which will examine the effects of chemicals likely to be ingested with food.

Manufacturers of foods, of materials used in food processing and packaging, of chemicals used as pesticides and as additives in the food industry, are included in the initial membership of the new Association.

(iv) *The Medical Research Council*

For many years, the Medical Research Council has supported an extensive programme of research in the field of occupational health. Certain of the Council's Units are actively engaged on research on the toxicity of pesticides to men and to animals. Investigations would, in general, be initiated in cases where evidence indicated a possible new health hazard among users of pesticides.

(v) *The Chemical Defence Experimental Establishment (Porton)*

This Establishment is concerned with some classes of compounds which are chemically related to compounds used in agriculture, such as the organophosphorus insecticides, and has very extensive analytical and medical experience in this field, including protective measures required in the handling of toxic chemicals. The Establishment is available to advise on the treatment of possible cases of poisoning by toxic chemicals and is carrying out research into improved methods of prophylaxis and therapy.

(vi) *The Nature Conservancy*

For some time the Nature Conservancy has been concerned about the impact on wild life of the use of toxic chemicals in agriculture and, in fact, participated in experiments mentioned in the Third Report of the Zuckerman Working Party. A toxic chemical and wild life section was set up in the spring of 1960. The Conservancy has supplied us with information on its research programme, which includes survey and ecological studies and long-term experiments on the continued use of selected representative chemicals. It is co-operating, as far as its resources and long-term objectives allow, with the numerous organisations carrying out research on the ecological effects of toxic chemicals.

(vii) *The Society for Analytical Chemistry*

The Analytical Methods Committee of this Society has a Pesticides Residues in Foodstuffs Sub-Committee, which collaborates with the Association of British Manufacturers of Agricultural Chemicals and the Scientific Subcommittee of the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage, in the study of methods of residue analysis. The Society has also financed a research investigation into the application of bioassay methods for the determination of pesticide residues.

(viii) *Industry*

Much research is done by industry in discovering and developing improved types of pesticides and in supplying the information required under the Notification Scheme, particularly on toxicity and residues. The number of new chemicals

currently proposed as pesticides indicates considerable activity in the search for more selective, more efficient and less poisonous products. Pesticide residue determinations form a substantial part of the development programme of a new pesticide, and industrial laboratories have informed us of what they are doing in this field. We note, also, that there is close collaboration between the Ministry of Agriculture, Fisheries and Food and the Association of British Manufacturers of Agricultural Chemicals on official committees working out acceptable methods of analysis of pesticides, both as formulations and as residues.

VIII. SURVEY OF EVIDENCE

35. In this chapter we discuss the evidence received, under headings covering the various aspects of our field of enquiry. Conclusions reached here in regard to research needs are collated as recommendations in the succeeding chapter.

(a) Hazards to Workers and Others

36. The main comment made to us on the subject of worker safety was that workers were insufficiently trained and supervised in the safe use of toxic chemicals, so that some accidents occur which could have been avoided; this comment applied only to farm workers and not to employees of contractors. It was claimed that the multiplicity of trade names made it difficult for users to know exactly what they were using and whether it was covered by the Regulations. The workers' unions were of the opinion that not enough was done to enforce the Regulations; in particular, they considered the Inspectorate was too small.

37. In order to see the subject in perspective we considered various related statistics. The average number of deaths annually from accidents of all kinds on British farms over the period 1956–60 was 140; there was no recorded instance of the death of an agricultural worker due to a pesticide. In 1960 72 deaths were caused by farm machinery, 10 by animals, 17 by falls, 12 by blows and wounds, five by guns and seven through miscellaneous causes. In the 8-year period 1946–53 before the introduction of the Regulations to control the use of the more toxic pesticides (paragraph 31 (iv) and Appendix D) there were eight deaths from these substances. In the eight years which have elapsed since the Regulations came into force in March, 1953, one agricultural worker died as a result of poisoning; this death occurred in 1955 from the use in greenhouses of ethylmercury phosphate. This substance is now used only in two special factory premises for the treatment of sugar beet seed and is no longer available to agricultural workers.

38. Apart from fatal accidents there are, on an average, about 20,000 non-fatal accidents on British farms each year, of which less than 5 are from chemical poisoning. In the period 1953–60, fifty reports of non-fatal illness among workers, alleged to be caused by substances named in the Regulations, were received and investigated. Of these 28 were confirmed, 16 could not be so established and 6 were due to different causes. In addition there were 12 reported cases of illness to agricultural workers from pesticides not covered by the Regulations; of these one was confirmed, seven could not be confirmed and four were found to be due to other causes. It will be seen, therefore, that since the introduction of the Regulations, the incidence among agricultural workers of accidents due to toxic chemicals has been very small, compared with other occupational risks to those workers.

39. The Ministry of Agriculture, Fisheries and Food's Safety Inspectorate (paragraph 31(iv)) is charged with the enforcement of the Regulations and makes, on an average, 1,200 visits each year on matters relating to poisonous substances. Since the Regulations came into force, 29 prosecutions have been brought.

40. The suggestion was made to us that the existing voluntary arrangements for the periodical medical examination of agricultural workers using the more toxic pesticides should be made compulsory. The view was expressed that the workers' unions would probably encourage regular blood testing, where necessary. While we have no evidence to suggest that compulsory medical examination, including blood tests, is necessary, we agree that if and when groups of suitably exposed workers can be found, an investigation might well be carried out to ascertain the value of the information obtainable from such tests.

41. It seems to us that the requirements of the Regulations have been successful in giving agricultural workers the protection they have the right to expect against the more toxic chemicals in use. These requirements have played a material part in the decreased use of the highly toxic Part I and Part II chemicals, as shown by the figures in paragraph 27. The need to comply with the Regulations makes the use of these pesticides troublesome. Farmers and workers clearly prefer to use pesticides that require little or no protective clothing, so that their choice, if they have one, is for a non-regulated as against a regulated chemical; or for one in Part III of the Regulations in preference to a Part I or Part II chemical. This attitude, in turn, has stimulated manufacturers to produce less poisonous materials.

42. Nevertheless, some of the regulated chemicals continue to retain their value as pesticides and it has been contended that the statutory precautions for some of the chemicals err on the side of safety and are too onerous. Workers believing this may ignore the statutory precautions and perhaps place themselves in jeopardy. We recognise that there may be some justification for this contention, in that the Regulations were drafted at a time when little scientific evidence was available on the actual hazards associated with the use of these chemicals. We recommend, therefore, that research should be carried out to determine the precise protective measures required when using regulated chemicals, both with established and with new techniques.

43. Although all products containing chemicals scheduled in the Regulations are required by the Poisons Regulations to bear the name of the poisonous ingredient on the label, we think the labelling of some could be improved, for example, by the use of pictorial symbols. We understand that discussions on the labelling of pesticides, from the safety aspect, are in progress between the Government and industry.

44. It has been suggested that ill effects to operators may follow repeated exposure to pesticides over the years. Workers overseas in the public health field are exposed for months on end, year after year, to insecticides like DDT and dieldrin, and the desirability of carrying out long-term surveillance on their health has been emphasised in reports from the World Health Organization. In our opinion such studies are not called for here because agricultural workers in this country are not exposed to pesticides over long periods.

45. Safety cannot be assured unless farmers and agricultural workers are aware of the nature of the product they are using and of the dangers that may be attached to its use. They will then realise that the precautions to be taken, either voluntarily or compulsorily, are no more and no less than essential measures for their protection. These are matters of education and training. The Agricultural Departments are best placed to carry out the work, both through their inspectors and by the use of advisory literature. From what we have been told, Government Departments accept this task and are doing all that they can to discharge it.

46. The highly toxic gas hydrogen cyanide has been in use for over fifty years, as a fumigant for the control of insects and rodents in goods and buildings. Although Regulations exist which apply to such uses, occasional accidents still occur with this substance. The hazards from this fumigant are fairly well known and accidents appear to occur from lapses in operational procedure rather than from a lack of knowledge calling for further research.

47. Spraying hazards to persons other than operators appear to be small. Although bystanders and passers-by could conceivably be affected on entering the area that is being, or has been, sprayed or dusted with toxic chemicals, no such cases have come to our notice. A single exposure to spray drift will not deposit enough of any pesticide to affect the health of a bystander or passer-by. The Ministry advises on how to avoid such accidental exposure and the recommendations for the safe use of a chemical include, where necessary, advice to keep unprotected persons from treated areas for a specified time after spraying has taken place. In our opinion, the problem does not call for further research.

48. If containers of pesticides are not properly cleansed after use and are carelessly thrown away, passers-by, particularly children, who investigate them are at risk from the dregs of the chemical in the container. A fatality occurred in 1960, when a non-agricultural worker handling empty tins died from contact with the dregs of a toxic chemical. The rendering safe, and the safe disposal, of such containers must be dealt with by education and advice; no research aspects are involved.

(*b*) *Hazards to Consumers*

49. The Second Report of the Zuckerman Working Party dealt comprehensively with the possible hazards to consumers who eat food which has been treated with, or exposed to, pesticides. The enquiry revealed no evidence of fatal or non-fatal illness that could be attributed to the presence of toxic chemical residues in food entering the market. The Report recommended that an advisory committee should be appointed, to deal with problems relating to consumer risks arising from the use of toxic substances on agricultural products and in the storage of food, and that manufacturers and importers should submit full information to Government Departments about new toxic substances which they proposed to market. These recommendations resulted in the establishment of the present Advisory Committee on Poisonous Substances used in Agriculture and Food Storage, and in the creation of the Notification of Pesticides Scheme, which are described in paragraph 31 (v) and Appendix E.

50. From the information given to us, we are satisfied the Scheme is working well and providing the safeguards to the consumer which it was intended to establish. Indeed, the existence of the Scheme in this country, and of like arrangements in other countries, has led to a situation in which pesticides

receive as much scrutiny in regard to their toxicity to mammals, as do many drugs and more than the majority of chemicals to which workers in industry may be exposed. We emphasise this point because from the evidence given to us, we gained the impression that there was a widespread belief that new pesticides were used without any kind of prior assessment of their harmful effects.

51. Some statements made to us clearly arose from anxiety about pesticide risks in general. For instance, one suggestion was that small amounts of pesticides in foodstuffs are possibly responsible for certain human diseases which have been recognised only recently and to which no definite cause can yet be assigned. There is no evidence to support this suggestion; these diseases do not particularly affect those most in contact with pesticides, such as workers regularly handling them in manufacture, formulation and application. Further, one such disease brought to our attention was medically recognised several years before the pesticides in current use became generally available.

52. It was suggested to us that possible long-term, cumulative effects may arise from the continued ingestion of food containing traces of pesticides, leading ultimately to a state of chronic poisoning, the real cause of which may not at present be recognised. The view was also expressed that if traces of a toxic material are taken over long periods, eventually some adverse reactions will appear.

53. We have found no evidence of chronic effects from the ingestion of traces of pesticides in food. Any substance may accumulate in the body if the daily dose is great enough. Before accumulation can occur, the daily dose must be greater than the amount of the chemical which the body can eliminate, by excretion or metabolism, in the course of twenty-four hours. In the case of certain inorganic substances, especially metals, the body can deal with only relatively small amounts. For example, it can cope with only about one milligramme a day of lead (a constituent of a once widely used insecticide). But the body can deal with considerably larger amounts of most organic chemicals, among which are included all the modern pesticides, so that with such materials the risk of accumulation is correspondingly small. Thus, if a pesticide residue occurs in a foodstuff in a normal amount following the approved use of the pesticide, there is every reason to expect that the body will be able to deal with it. Furthermore, not all foodstuffs are treated with pesticides and of those that are, only a very small proportion is treated with toxic materials (paragraph 27). Some pesticides are unstable and break down rapidly, leaving no residue at harvest. Others may or may not leave a residue, depending on the method of use or time of application. Where the use of a pesticide is known to lead to a residue in the harvested crop, the Advisory Committee lays down conditions of use which are practical and which include the period which must elapse between application and harvesting, to allow the residue to fall to an acceptable level.

54. An acceptable level is one which medical experts accept as falling far below the amount which would be deleterious to health, if consumed daily in the food. It is usually based on a study of the effects of a pesticide on laboratory animals. In the few instances where measured quantities have been given to man, the responses of man and laboratory animals receiving equivalent doses have been in close agreement. An acceptable level of a pesticide residue is normally one which would result in the consumer, if he were to eat treated produce daily,

receiving a dose 100 or more times *smaller* than the dose which, fed to animals every day of their lives, produces a minimal toxic response or no response at all. Practically all the new pesticides have been fed to laboratory animals for their life span and we know of no example where the reaction at the beginning differs from that seen towards the end of the life span.

55. These considerations have led us to conclude that pesticides, consumed for a long time at levels at present agreed to be acceptable as defined above, would have no adverse effect on the health of the consumer.

56. Evidence was given to us that the efficient control of pests may sometimes be obtained with lower dosages of chemicals than those normally recommended. The development of this line of enquiry requires knowledge of the minimum levels of deposit needed to give control, the distribution of the deposit on the treated surface, and the biological activity of different types of deposits. The nature of plant surfaces and its influence on deposition and absorption of pesticides is also relevant, as is the manner of formulation of the active ingredient. Research on these matters is being undertaken at several centres. It was clear to us that progress in this work must lead to reduced chances of hazard to consumers from pesticide residues and we strongly support the vigorous prosecution of such research.

57. Concern has been expressed about the possible hazard to anyone consuming pheasants or pigeons shot after they had eaten what amounted to a lethal dose of dressed grain. Analysis of muscles of birds found dead in circumstances that suggested they had been poisoned, showed the presence of dieldrin and mercury. In some cases the levels found were higher than would be considered acceptable in an article of food or drink that is regularly consumed but, as already stated, these acceptable levels are set to include a very big margin of safety. We do not consider that the occasional consumption of the flesh of birds, shot after having consumed a lethal dose of dressed grain, would result in dieldrin or mercury poisoning.

58. The possibility that a new pesticide may have a cancer-producing effect on mammals is always borne in mind when its potential toxicity is being considered. We note that a Standing Panel on Carcinogenic Hazards in Food Additives and Food Contaminants has recently been set up by the Ministry of Health, and that this Panel will include pesticides among the chemicals it will scrutinise.

59. With the many pesticides in current use, it is possible that a normal mixed diet might contain residues of several different compounds. This possibility is taken into account when acceptable residue levels are considered. Laboratory studies have revealed isolated instances where one organo-phosphorus pesticide has markedly enhanced the effects of another pesticide of the same class; this phenomenon has been referred to as 'potentiation'. Potentiation has, however, been detected only at levels well above acceptable levels, and the enhancement is small compared with the safety factor involved. It has been suggested that this phenomenon should be studied in all combinations of all pesticides. This would involve a volume of experiment that would overwhelm the available resources and the findings would have little or no bearing on hazards to the consumer who, if he ingests a pesticide residue, does so at a level far below that capable of producing a detectable effect on laboratory animals.

60. We have considered the question of the control of the levels of pesticide residues that may remain in or on food. The need for such controls is generally recognised and in certain circumstances proceedings under the Food and Drugs Act or its Regulations, involving crops containing excessively high residues of pesticides, could be instrumental in curbing growers who, in ignorance or through neglect, fail to observe the conditions of use. Control could be achieved by legislative action, such as the establishment of official tolerances, that is, of maximum permitted residue levels, or by other means, but its full consideration is outside our terms of reference. We have, however, found it necessary to survey the various approaches to this difficult problem, since some of the possible courses of action would require much further research.

61. In looking at the problem of maximum pesticide residue levels, we have examined particularly the system of statutory tolerance levels established in the U.S.A. These figures, which are given for every pesticide and crop, are widely misinterpreted as 'safety levels'; they are, in fact, the maximum amounts of residues which should result from the recommended application of any pesticide and which are also acceptable to the health authorities. The safeguard is thus the legal requirement to apply pesticides correctly, not the tolerance figure itself, which serves merely as a means of detecting improper or incorrect practice so that appropriate action can be taken. It must be recognised that levels established in a particular country under such a system cannot necessarily be applied elsewhere. Any residue level that is established must be related to the residue which results from the correct use of the product in protecting plants and animals from pests and diseases. It would be unrealistic to establish arbitrary levels where adequate supporting data do not exist, or where sufficiently sensitive and reproducible analytical methods are not available.

62. The recommendations for the safe use of a pesticide made under the voluntary Notification Scheme are based on the fact that any residues which result from the recommended use will be free from health hazard. The principle in this country, as in North America, is to establish a code of practice, and we consider adherence to such a code, by careful observance of the instructions given on the label, a more practicable safeguard than the establishment of statutory maximum residue levels for all pesticides. The actual levels resulting from the recommended use of pesticides in agriculture are lower than the levels that would be considered the maxima acceptable on the basis of any known threat to health presented by those levels.

63. We see no justification for recommending the very large amount of research that would be necessary to provide the data needed to set up, for the United Kingdom, statutory maximum levels of residues of all pesticides.

64. We were informed of the procedure followed by the Advisory Committee in arriving at its official recommendations for the safe use of a pesticide. Most, if not all, of the residue data on which the consumer precautions are based, are provided by the notifying firms. While there is no cause to believe that the information provided in this way is not well founded we consider, nevertheless, that facilities should be made available for independent residue data to be obtained. This could be done, for example, by sampling and analysing crops from the trials carried out by workers in official agricultural advisory services and research stations. In this way official recommendations on consumer safety would be based on residue data from more than one source.

65. It is recognised that the full uses of a new pesticide cannot be assessed until it has been tried in practice under varying climatic and soil conditions over a period of two or more years. Just as a pesticide may vary in efficiency under different conditions, so, too, may the residue in the treated crop vary. We recommend, therefore, that selective surveys over several years should be made on crops known to have been commercially treated with pesticides, to confirm, or otherwise, that residues occurring in crops grown under varying conditions are still not in excess of acceptable levels. These surveys should include both home-grown and imported foodstuffs.

66. We gave careful consideration to a proposal that 'tracers' or 'markers' should be added to pesticide formulations, as an aid to the detection and determination of residues in crops treated with these formulations. We concluded that the practical difficulties in putting this proposal into effect were such that it would have very limited use.

67. A plea was made to us that official guidance should be given to the authorities responsible for administering the Food and Drugs Acts, on the 'safety limits' for pesticide residues in foodstuffs. This guidance would be used when considering whether to prosecute on the basis of the analytical results provided by their public analysts. For the reasons given in the foregoing paragraphs we were unable to support the proposal. We think it desirable, however, that serious consideration should be given to a proposal that the official recommendations for the safe use of a pesticide should include a statement to the effect that, when the pesticide is applied properly according to the instructions provided, the residues in a treated crop would not be expected to exceed a certain amount. At the same time it would have to be made clear, without possibility of a misunderstanding, that any such figure should not be interpreted as a 'safety limit'.

68. Our recommendations above cannot be adequately implemented without improvement of some existing methods, and the development of new methods, for the detection and determination of residues of pesticides and their metabolites in plant and animal tissues. We strongly recommend that analytical research of the nature detailed in paragraph 140.2 should be supported and encouraged.

69. Often no satisfactory or agreed method of analysis is available; or a precise method is known, but is slow or difficult in operation as, for example, that for the determination of dieldrin in flesh. We consider that there should be an official central source of information and advice on analytical methods for pesticide residues, available to analysts in this country.

(*c*) *Hazards to Farm Livestock*

70. Although accurate estimates of the incidence of poisoning of farm livestock, or of losses due to agricultural or other chemicals that may be found on farms, were not available to us, we believe that the accidents or incidents brought to the attention of the Central Veterinary Laboratory of the Ministry of Agriculture, Fisheries and Food by veterinary surgeons, veterinary investigation officers and other Ministry officials provide a reasonable basis for assessing the relative importance of different toxic chemicals. The records from these sources made it clear that the poison hazard to farm livestock lies almost entirely in metallic compounds, few of which are pesticides; indeed, the greatest danger of poisoning to farm livestock (particularly calves) is from licking lead-painted surfaces.

71. The second most common cause of death from poisoning is arsenic, but the withdrawal, after 1960, of alkali arsenite potato haulm killers should lead to a marked decrease in such cases. Nevertheless, carelessness in the use and disposal of established arsenic-containing materials, such as foot-baths and some sheep dips and timber preservatives, may continue to cause some deaths.

72. Chronic copper poisoning of farm stock has increased in recent years from the indiscriminate use of 'copperized' mineral supplements as an insurance against the possibility of copper deficiency. Copper metabolism in sheep and cattle is an extremely complex matter. In certain circumstances copper may accumulate in sheep and cattle to a level which may have unfavourable effects on the animals and ultimately cause death. An inadequately realised danger also arises from access of stock to land where copper sprays have been used; poisoning of sheep through grazing in copper-sprayed orchards is not unknown. Warnings appear on the labels of most proprietary products, where appropriate.

73. Hazards of the kind discussed in the above paragraphs do not pose any problems of research.

74. Formerly, losses occurred from rodenticides containing arsenic, zinc phosphide and other acute poisons, but these losses have almost ceased to occur, as such rodenticides have been largely superseded by warfarin. This much safer rodenticide, in turn, can constitute a danger to animals, particularly pigs, but awareness of this fact and attention to safe methods of use have reduced losses due to it.

75. We have no evidence that harm has resulted to animals, in twenty-five years or more, from the proper use of the established organo-mercury dry seed dressings, but we consider that more information is needed on the toxic properties to livestock (including poultry) of seed treated with the more recently developed seed dressings containing new organo-mercury compounds applied in liquid form. Seed dressed with certain mixed fungicidal-insecticidal dressings can certainly be lethal to adult poultry.

76. The disposal of surplus dressed seed can pose an economic problem to farmers. We were informed that preliminary experiments were in progress on the effect of feeding grain, treated with a liquid mercurial dressing, to poultry. We recommend that further experiments should be initiated on the effects of feeding such seed to farm animals, including poultry, both as regards the health of the animals themselves and the possible contamination of their flesh, and products such as eggs.

77. Very few cases of poisoning of farm animals have been recorded from the proper use of the organo-chlorine and organo-phosphorus insecticides and even fewer from fungicides or herbicides other than the alkali arsenites.

78. Pesticides may be administered to, or applied to the skin of, livestock in order to control parasites. The detection and estimation of any residues of such pesticides in meat, milk or eggs from treated animals sometimes present considerable difficulties. The development of more practicable and reliable analytical methods may assist in the diagnosis of suspected cases of poisoning of livestock by pesticides.

(d) *Effects on Wild Life*

INTRODUCTION

79. Many statements have been made to us on this topic and we are aware that the subject has attracted much public comment and discussion. We have been impressed both by the depth of feeling aroused and by the difficulty of resolving some of the issues by investigations of a kind falling within our terms of reference. Scientific research alone cannot decide, for example, whether the economic advantages accruing from a given method of pest control outweigh, from the collective as well as the individual standpoint, the various possible disadvantages of resulting changes in population of wild plants and animals. We are convinced, however, that any decisions taken ought to be based as far as possible on factual information obtainable only by research of one kind or another and we have noted that past misunderstandings and controversies could often be traced to a lack of such information.

80. It is known that the use of pesticides has sometimes led to deleterious effects on wild life. It is possible that more research carried out before the marketing and use of the pesticides might have indicated the likelihood of such effects. This is by no means certain, however, for there are some effects of wide-scale use that could not be expected to become evident from experimental-scale tests. There is thus a need to extend research on new pesticides into the field in the early years of their commercial use.

81. The statements and representations made to us contained references to the need for a wide range of biological studies, including the ecology of plants and of vertebrate and invertebrate animals. They broadly covered the fields reviewed in the Third Report of the Zuckerman Working Party. The suggestions and comments we received were more frequently concerned with wild birds and mammals than with any other form of wild life and we have, therefore, considered these in greatest detail in this Report.

82. In some instances the concern was simply to ensure maximum efficiency in controlling a pest; in others, to preserve game or to protect wild species. Some of the statements made to us were based more on apprehensions as to what might occur in the countryside, than on direct observations or proven facts. Very few suggestions for specific lines of research were received.

EFFECTS ON WILD PLANTS

83. Herbicides are of value to the farmer in so far as they control troublesome weeds without harming crop plants already growing, or about to be sown, in the treated fields. It follows that they must to some extent be selective, and manufacturers normally study their effects on a range of plant species before putting them on the market. Investigations on specificity are also carried out in Government-sponsored research stations and in some university departments. At present, however, most of the chemicals used as herbicides are no more than broadly selective; as a result, some weed species multiply in the absence of competition from others. The situation has so far largely been held in check by the development of new herbicides with different ranges of specificity. But the long-term effects of using these chemicals are difficult to foresee. Besides the multiplication of weeds that survive herbicidal treatment, there is always the possibility that some weeds, now susceptible, may develop resistance to herbicides, as have certain insects to insecticides. There has so far been little evidence of this, but there is obviously a need for the position to be kept continually in review by research workers with a good knowledge of weed ecology.

84. Widespread and justifiable concern arises from the indiscriminate application of herbicides to roadside verges, which are thereby made very unsightly for a time and lose that floristic diversity which is so pleasant a feature of many of our country roads. The Nature Conservancy took up this matter with the appropriate national and local authorities and agreement was reached about the classes of roads which might reasonably be treated and about the manner and timing of the treatment. That agreement has not always been observed. Still greater apprehension has been felt about the effects of accidental drift, especially if aerial spraying should become a common practice; this subject is further discussed in paragraphs 130–136. There is also apprehension among botanists about the danger to interesting plant communities and rare plant species if herbicidal sprays should be used extensively on rough hill-grazings and other natural or semi-natural vegetation.

85. Instances of misuse are scarcely matters for research and must be dealt with mainly by administrative action; but it is, nevertheless, important that the possible consequences of all kinds of use or misuse should, as far as possible, be known and foreseen.

EFFECTS ON PREDATORY AND OTHER BENEFICIAL INSECTS

86. There are a number of instances on record where the use of certain pesticides has led to the emergence of previously unimportant pests. The wider the range of insects killed by an insecticide, the greater becomes the danger to beneficial insects. Thus the use in some parts of the world of 'wide spectrum' insecticides for the control of certain pests on cotton, fruit and other crops, has sometimes been followed by serious outbreaks of other pests. The classic example in this country is the serious increase in fruit tree red spider mite, which followed the use, first of tar oil winter washes, then of DNOC sprays, and later DDT and BHC. Workers in the field of economic entomology are fully aware of these dangers and are actively seeking ways of achieving maximum benefit with minimum harm. One aim is the development of insecticides more specific to particular pests. In Nova Scotia, the use in apple orchards of more selective insecticides for several years has given promising results. Other objectives are a better and more comprehensive knowledge of the inter-relationship of pests and their parasites and predators, and of the relationship between crop damage and pest densities, to avoid too frequent application of pesticides, and to enable these applications to be timed to reduce harm to beneficial insects.

87. These lines of work should continue to receive full support and we recommend that when a new insecticide is introduced, every effort should be made to study its effect, not only on the pests to be controlled, but also on some of the predators and parasites likely to be involved.

EFFECTS ON WILD BIRDS AND MAMMALS

88. Since 1955 deaths of wild life from schradan, arsenites and DNOC have decreased markedly and now seem to have ceased. This is presumably because schradan has been almost completely superseded by less toxic chemicals, arsenites have been voluntarily withdrawn, and the amount of DNOC used has been drastically reduced by the advent of other equally efficient and far less toxic herbicides. On the other hand, deaths of birds, particularly in the springtime, resulting from the consumption of seeds dressed with certain insecticides, have greatly increased; they are discussed in some detail in paragraphs 92–95.

89. In considering the pattern of future research we have noted that very few of the many chemicals introduced into United Kingdom agriculture since the War have been shown to have adverse effects on wild birds and mammals. Some chemicals, for one reason or another, have been replaced within a year or two, often before detailed investigation of their effect on wild life could have been carried out. Although this may be reassuring to the ecologist and naturalist, in that adjustments often take place before losses become irreparable, it adds to the difficulties of research, which in this field is a lengthy process.

90. The effect of pesticides on wild birds and mammals has also attracted considerable attention in North America and in continental Europe. The immediate findings were usually specific to the conditions in which the investigations were conducted, for the environments and the pests controlled differed from place to place. In this country no widespread control or eradication schemes have had to be carried out, similar to those in the U.S.A., where extensive areas have been sprayed from the air, for example, to control the imported fire ant. However, we found it profitable to examine the investigational techniques used. We noted the valuable study of populations of the American 'Robin' (*Turdus migratorius migratorius* L.) as affected by spraying against the elm bark beetle, and were impressed by the considerable amount of census and observational work needed to measure the changes that occurred. The biological observations were accompanied by chemical analyses, as were investigations recently undertaken in the United Kingdom, on deaths of birds from eating dressed seed.

91. Ecological studies on wild life, mainly birds and mammals, are being carried out in certain research laboratories, university departments and under the auspices of the British Trust for Ornithology. Specific investigations of an *ad hoc* nature already undertaken include work to determine the effects of new usages of chemicals in the field, such as the investigation into the effects, on a number of species of wild life, of spraying with endrin to control field voles. We would like to see investigations made on the 'pick-up' of BHC and other organo-chlorine insecticides by invertebrates on and in soil to which the chemicals have been applied, and on the effect, if any, on birds and mammals which consume these invertebrates. In our opinion these types of studies are of basic importance and should be encouraged.

SEED DRESSINGS

92. Much of the evidence given to us concerned toxic seed dressings and their effects on birds and other wild life. We therefore took particular note of the reports on this subject and though we were not able to accept all the implications in these reports, they confirmed that mortalities had occurred, and were occurring, on a large scale. For example, the Joint Committee of the British Trust for Ornithology and the Royal Society for the Protection of Birds stated that 251 incidents involving deaths of birds and mammals had been referred to it between mid-February and Mid-May, 1961.

We have enquired into the events that followed the introduction of the dressings concerned.

1. The first deaths, in the spring of 1956, were unexpected and apparently on a small scale. The only change in practice about this time was the introduction of the insecticides aldrin and dieldrin as cereal seed dressings, though this was not recognised at the time as likely to affect bird life. Preliminary experiments

at the Veterinary Laboratory of the Ministry of Agriculture, Fisheries and Food showed that seed treated with the new dressings could be lethal to captive pigeons.

2. The early incidents, and others which followed, were investigated, but the evidence obtained was circumstantial and the presence of the suspected chemicals in the bodies of birds picked up in the fields could not be established beyond doubt because means for carrying out the analytical tests for these chemicals in animal tissues were not then available. Moreover, the new dressings were not widely used at this time and their potential dangers were not fully appreciated. There were problems of organisation and manpower in arranging for a more complete enquiry to be made, which problems could not be overcome at the time.

3. By 1960, when the number of deaths was giving cause for concern, the earlier enquiries had been developed into a systematic investigation involving a large number of field and laboratory workers. The workers involved had to be taken from their usual duties and allocated temporarily to this investigation.

93. On the enquiries carried out we make the following general comments:

1. The reports on field incidents assembled jointly by the Royal Society for the Protection of Birds and the British Trust for Ornithology, and by the Game Research Association, provided information that was most valuable in indicating the scale and general distribution of the casualties to wild life. Nevertheless, the information gathered from observations in the field was often deficient. This was partly because of the difficulties experienced by observers in finding out what chemicals had been used in the localities in which such casualties were observed, and partly because analyses of the bodies found could not be undertaken.

2. Although the field reports amply demonstrated that many deaths had occurred among various species of birds and some mammals, a number of important questions were left unanswered. The issue was confused by lack of data on the numbers of deaths from natural and other causes among different species and their relation to the total populations in given parts of the country. We recognise that this is largely due to the laborious and time-consuming nature of the effort needed to assess wild life populations in the field. We consider there is a great need to improve our knowledge of bird and mammal populations generally and of their normal mortalities, and it is clear that useful work could be done by amateur observers. Such knowledge would greatly assist the investigation of any future occurrence of casualties on a significant scale.

3. Chemical analyses of the carcases were essential to determine which chemicals, if any, were present and in what amounts. This information was needed to support or refute the charge that chemicals had caused death.

4. Before a correct interpretation could be made of the results of the analyses it was necessary to establish standards, e.g. by determining the level of chemical present in various parts of the carcase of a bird or animal which had been given a lethal dose of that chemical. Such knowledge was valuable also in preventing wrong inferences being drawn as to the cause of death when only traces of a chemical were found.

94. We have been informed of the measures agreed between the Ministry of Agriculture, Fisheries and Food, the agricultural chemicals industry and other interested organisations, at their meeting on 29th June, 1961. These consist of

not using dressings containing aldrin, dieldrin and heptachlor for spring sowings, their use being confined to the dressing of autumn-sown wheat, when there is a real danger of attack from wheat bulb fly.

95. We consider it important that a continuing survey should be made for the next year or two, to assess the effects of these measures and we note with satisfaction that the Ministry of Agriculture, Fisheries and Food intends to do this. It is expected that one result will be that BHC will again come into greater prominence for seed dressings. We therefore recommend a fuller study of the effects of this and other chemicals used in seed dressings on wild life generally, including correlation of the amounts found in the tissues with the dosages ingested.

GENERAL COMMENT

96. In 1955 the functions and composition of the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage were modified, to make it clear that it was also '(*a*) to receive and consider evidence and reports of research on the risks to wild life resulting from the introduction of new chemicals; (*b*) to bring to the notice of the appropriate bodies, when necessary, problems relating to the effect of toxic chemicals on wild life which need investigation'. Under the Notification Scheme manufacturers have been providing information on chemical and physical properties, toxicity, and residues, all of which relate to this question. We were pleased to note that agreement was reached in 1961 to add an Appendix on Wild Life to the Notification Scheme. The effect of this will be to widen the range of species examined before a new chemical is introduced, and to provide for observations to be reported from the field during the initial stages of the introduction of a pesticide into practice.

97. In any attempt to foresee the risks to wild life before a new chemical is introduced, the most important factors are, in our opinion:

1. the birds or mammals which will come into contact with or consume the chemical, the amounts which they may consume, and the period over which this may take place;
2. the toxicity of the chemical to the species in question; and
3. the chemical and physical properties of the substance, such as volatility and persistence on the ground and in the crop.

98. Considerable information is usually provided by manufacturers on the second and third of these factors and this is likely to be augmented as a result of the addition of the Wild Life Appendix. Information on the first factor is often lacking and may well not be obtainable until after the substance has gone into general use; this limits the possibilities of predicting risks. Nevertheless, increased attention to this factor, and the investigation of incidents as they occur, should enable the advice in the Wild Life Appendix to be reviewed periodically and, if need be, made more specific.

99. The research involved may be roughly divided into short-term and long-term. The short-term includes investigations of the kind required under the Notification Scheme and the prime responsibility for carrying them out rests with manufacturers. We endorse the principle that manufacturers should investigate their products both in the laboratory and in the field, and the Wild Life Appendix will give guidance for this. At present, search for new and less hazardous chemicals is carried out more by industry than by officially sponsored

organisations. We see no reason for suggesting any alteration in this position. There are other short-term researches which are more the concern of Government Departments, such as work on methods of assessing the number of bird deaths occurring during a field trial, e.g. by ascertaining what proportion of a given number of dead bodies placed in a field is detected by direct inspection, what proportion is removed by predators, and how rapidly this occurs. Another example is research on the most reliable methods for carrying out surveys or enquiries into incidents reported from the field. We recommend that these short-term researches should be intensified.

100. Long-term research includes studies of possible changes in selected habitats over periods during which certain pesticides are, or have been, used. The successful prosecution of such studies is dependent on a knowledge of the ecology of localities such as hedgerows, grasslands, woodlands, scrub and ditches, which act as important reservoirs of wild life. The Nature Conservancy is the official organisation primarily responsible for such studies, but it has not been able, so far, to attack these problems on a large scale. When planning studies on changes of habitat it must be remembered that at present much of the background information is not available. Amateur observers and workers at universities and research stations are studying the biology, habits and life histories of individual species of wild birds and animals. These studies are obviously very desirable.

Bird repellents, for incorporation in seed dressings or for direct application to certain crops, would have great potential usefulness, but none of the preparations so far tested has proved sufficiently effective in practice; nor has work on the physiology of taste in birds suggested promising lines of attack. Nevertheless, further research in this field is desirable.

101. Close liaison is clearly essential between those engaged in the various researches into wild life, whether short- or long-term. We deal further with this matter in the chapter on 'Initiation and Co-ordination of Research' and suggest that the naturalists' societies should be brought fully into consultation. We also suggest that the Government should make permanent arrangements to ensure that incidents can be investigated on the spot, at an early stage, whenever there is evidence that an appreciable number of fatalities might have been due to toxic chemicals. These arrangements should be supported by adequate facilities for chemical analysis and by research into methods for detecting pesticides in the bodies of wild birds and animals.

102. In the chapter on 'Recommendations' we summarise the research subjects and problems which we have discussed in this section and to which we recommend that further attention should be devoted.

(*e*) *Effects on Honeybees*

103. The poisoning of honeybees by pesticides is not a new problem, but in recent years there has been a shift in the time of year at which the damage occurs.

104. When arsenicals were commonly used in orchards, they caused much damage to bees in the spring, but such sprays have now been largely superseded by others, which give remarkably little cause for complaint by bee-keepers. There is now generally good co-operation between growers and bee-keepers over the movement of hives to orchards for the pollination of fruit blossom, and the timing of spray programmes can be, and to an increasing extent has been,

arranged to avoid the application of chemicals toxic to bees during the flowering period. Incidents involving the poisoning of bees occur occasionally; for example, in 1961 a grower used an aldrin wireworm dust on strawberry plants in flower, with the result that 12 colonies of bees were severely affected. Nowadays such incidents are exceptional in fruit-growing areas.

105. At the present time the chief cause of losses of honeybees is the spraying or dusting, while the plants are in flower, of field beans and brassica crops grown for seed. This became particularly noticeable during late May to early July, 1959. A similar picture emerged in 1960, and again in 1961. The chemicals most frequently implicated have been certain organo-phosphorus compounds (demeton-methyl, dimethoate and parathion), dieldrin and BHC. Affected colonies of bees lose their workers foraging on the crop. Although the colonies may recover their strength within a few weeks, a loss of foragers, even for a short period in June or early July, may mean the loss of a season's harvest of honey for the bee-keeper. There is also a reduction in the local population of pollinating insects.

106. Their strong homing instinct compels honeybees to return to their hives, even when poisoned. An accumulation of dead bees round the hive entrances would indicate that sprays poisonous to bees are being used in the vicinity. It could also be regarded as an indication of similar poisoning, on an appreciable scale, of other beneficial insects, both predators and pollinators.

107. Knowledge in this country of the effects of pesticides on honeybees is based on reports and samples of dead bees, received from bee-keepers by the National Agricultural Advisory Service Bee Advisory Unit, and on the results of tests for the presence of toxic chemicals in the bees. Methods of detecting toxic residues in bees are being investigated by the Department of Insecticides and Fungicides of Rothamsted Experimental Station, which has also undertaken the examination of samples received by the Bee Advisory Unit since 1955. On the basis of the samples received in 1959, it was estimated that at least 700 colonies of bees were depleted of their foraging bees in that year; and there must have been unrecorded incidents. Damage on a similar scale occurred in 1960 and, on a rather smaller scale, in 1961. In these three years most of the incidents occurred in the eastern half of England, between the Humber and the Thames, where it is estimated that there is a minimum of 36,000 colonies of bees.

108. If insect damage is to be prevented by current methods of pest control, some crops must sometimes be treated while they are in flower. Examples are February-sown field beans and some brassicas. Other field beans and brassica crops are likely to be treated while in flower, either because the need for earlier spraying was overlooked or because of delay in getting the work done. To deal with this situation the Ministry of Agriculture, Fisheries and Food introduced, in 1960, a scheme, covering some of the eastern counties, whereby warnings were passed on to bee-keepers in the localities concerned, of impending spraying operations which involved flowering crops worked by bees, and which had been given by farmers or spraying contractors.

109. The scheme had obvious limitations and proved only a partial success, but in 1961 a development was tried in Northamptonshire. Here a small working committee of five members was formed, representing farmers, spraying contractors, the county Bee-Keepers' Association and the Ministry's Divisional

Office, with the county bee-keeping instructor as organising secretary. The field crops in the county likely to be sprayed were plotted, the farmers were approached and local bee-keepers were enrolled to act as liaison officers between the farmers and other local bee-keepers. Numerous warnings of impending spraying operations were received and passed on, and several methods of closing hives during the danger period were tried. A full report on the working of this scheme has yet to be made, but we understand that no complaints of damage to bees were received and the indications are that willing co-operation between all the interests involved achieved good results. We were told that the report will be considered by the Ministry with a view to assessing its applicability to other counties where the risk of spray damage to bees is known to be high.

110. We consider that further research is required on:

1. control measures which could be applied outside the flowering period;
2. techniques for assessing the toxicity of chemicals to bees, both in the laboratory and in the field; and
3. methods for detecting and determining pesticides in bees suspected of being poisoned.

111. The addition of effective bee repellents to toxic sprays has often been proposed. Repellents would not reduce casualties to bees caught by a spray, but could reduce the risk of poisoning from residues on the sprayed plants and might be useful in sprays applied immediately before the flowers open. The search for effective repellents in this country and elsewhere has hitherto been unsuccessful, but any promising developments are worthy of further investigation.

(*f*) *Effects on Soil*

112. Some pesticides are applied directly to the soil to control insect pests, eelworms, fungi and weeds; others reach the soil when crops are sprayed. It has been contended that large areas may soon be rendered less fertile thereby, but no evidence has been submitted to us in support of this contention.

113. It is known that the soil in certain orchards in America, which were sprayed many times each year with lead arsenate, eventually became unsuited for the growth of various plants. Investigations showed that these soils had accumulated over 4,000 lb. of lead arsenate per acre. However, after treatment with ammonium phosphate and farmyard manure, either immediately or following a crop of rye (which is very tolerant of arsenic), good crops of quite a number of vegetables were grown.

114. In this country the relatively small proportion of orchards which are still sprayed with lead arsenate for the control of codling moth, is sprayed not more than three times a year, and there is no evidence, so far, that their soil is becoming less fertile. Most lead arsenate reaching the soil remains in an insoluble form for many years, but small quantities of arsenic can be removed by microbiological action, and small quantities of metallic elements are continually being removed by growing plants.

115. The only indication that has come to our notice that inorganic sprays, after long-continued use, may be having some effect in our soils, is from some research on orchards at Wisbech, by workers at the Rothamsted Experimental Station. It was found that very few earthworms were present in the soil of apple orchards sprayed for many years with Bordeaux mixture (which contains copper) for the control of apple scab, compared with the numbers in the soil of unsprayed areas.

The surface mat of grass was also atypical and peaty and the crumb structure of the soil below was poor. Fortunately, the orchard areas now sprayed with copper compounds are small and we believe that, if deleterious effects on the soil were observed, it would not be difficult to restore the fertility by appropriate treatment, as was done with some of the American soils overdosed with lead arsenate.

116. Whereas elements such as lead, copper and mercury are generally very persistent in soils, many of the organic insecticides and fungicides now being used on an increasing scale in orchards are broken down by soil micro-organisms and disappear completely.

117. A few, however, including aldrin, dieldrin and DDT, are very persistent, experiments having shown that the level of their residues in some soils decreases by only about one half in four to five years. Regular use of these chemicals in pest control programmes could result in an unobserved build-up in the soil, with effects it is difficult to foresee. Research is already in progress to determine these effects, but it is necessarily of a long-term nature. There is evidence, both from this country and from North America, that certain insecticides can be taken up in small amounts from the soil by plants and that the growth and flavour of some crops may be adversely affected. It is clear from this evidence that the amounts of these chemicals used in soils, or applied to crops as dusts or sprays, should be kept to a minimum. Although the subject is a very wide one and difficult to investigate, we consider these researches should be substantially extended. Meanwhile, we urge that the indiscriminate use of persistent insecticides in fertiliser mixtures, without regard to the degree of pest infestation of the fields to which they are applied, should be strongly discouraged.

118. The pesticides most widely used on agricultural land are the growth regulator ('hormone') type herbicides. These, also, are organic compounds which are broken down in the soil by the action of micro-organisms. They have been used on farms for fifteen years or more, without evidence of any adverse effect on soil fertility.

119. We are aware that new chemicals for use as pesticides are continually being developed, and that when they are first introduced into practice there can be relatively little knowledge of their long-term effects. For example, in recent years new herbicides, such as simazine, diuron and fenuron, have appeared and have been found to be very persistent in soil. Research in progress at present is concentrated mainly on their persistence and possible build-up in the soil, leading to a toxicity to plants. We would like to see the research increased and extended to a study of their effects on soil flora and fauna, and on soil fertility.

120. Reliable methods are now available for identifying and assessing some pesticide residues in soil. Although preliminary studies have been made by the Plant Pathology Laboratory in collaboration with the Potato Marketing Board and by the National Vegetable Research Station, little systematic work has been done to ascertain the build-up in the soil of persistent insecticides in agricultural or horticultural areas where routine pest control measures are regularly applied. We urge that fuller survey work of this kind should be put in hand without delay.

121. We should also like to see full support given to any work directed towards forecasting the incidence of soil pests in the field. In our opinion this is the most promising way of relating the application of pesticides to the need, so reducing the amount of chemical applied to the soil. Some valuable work in this direction has already been done on wheat bulb fly by the National Agricultural Advisory Service.

(g) Effects on Water and aquatic Wild Life

122. We noted that there is a Panel on Water Reserves and Farm Chemicals, consisting of representatives of the Ministry of Agriculture, Fisheries and Food, the Ministry of Housing and Local Government, and the Department of Scientific and Industrial Research. We were informed that its functions include advising Government Departments on the possibility of the contamination of underground and surface water by agricultural chemicals, guiding the preparation and collection of relevant data and deciding what practical experimental work is required.

123. We have received an interim report from the Panel and also the views of workers in research stations concerned with problems of this kind. From this evidence it is clear that information is already available about the persistence and movement of chemicals applied to soils. The chief factors influencing movement are the water-solubility of the chemicals and the type of soil to which they are applied. Many of the chemicals have low solubilities and are held by absorption on the organic and clay fractions of soils. That they are held by the soil is clear from the fact that their effects (such as taint from BHC and the residual insecticidal effects of DDT and dieldrin) are still detectable long after application. Other chemicals are broken down to a varying extent by micro-organisms, by hydrolysis or other reactions, or are lost by vaporisation.

124. An impression exists that the increasing number of new chemicals applied to the soil increases the risk of contaminating water reserves. But new chemicals are usually replacements for, not additions to, the old chemicals. They may be of lower mammalian toxicity and higher biological efficiency, enabling much less to be used per acre.

125. No cases of water pollution from pesticides by infiltration were reported to us in evidence. Although we think that a water contamination problem is unlikely to arise in this country, we consider that a limited amount of exploratory work is warranted.

126. Cases of poisoning of fish have been described in America due to run-off from treated areas. These have been from heavy applications, from the treatment of very large areas, or from heavy rains which washed the chemical into streams. In this country, the commonest cause of damage to fish has been the accidental spillage of chemicals, the discarding of surplus material or containers into ditches or streams, and the washing therein of containers or spraying equipment. Most of the incidents arose from carelessness or ignorance and ought to have been avoided. They emphasise the need for care in general handling, as well as in application, for example, under certain conditions of wind and when sloping ground is treated. They also emphasise the need for full instructions and adequate warnings on labels.

127. River Boards and drainage authorities require chemicals to control submerged aquatic species of plants, and search for chemicals effective for this purpose is being carried out. Clearly the use of such chemicals can offer to fish a hazard which may depend on the direct toxic effects of the chemical, both on the fish and on fish food, or may arise from de-oxygenation of the water. This condition may be caused by direct combination of the chemical with dissolved oxygen or, indirectly, by the decomposition of plants which are killed by the chemical. A chemical applied to kill water weeds may, at the same time, eliminate

other plant species which are valued for their beauty or for their scientific interest and importance. Clearly there should be no indiscriminate application of herbicides for the purpose of removing water weeds.

128. Further knowledge is needed on the toxicity of aquatic herbicides to fish, water plants and other aquatic organisms under conditions of field use. If the need for aquatic herbicides becomes a necessity in this country, a search should be made for suitably selective chemicals.

129. The Salmon and Freshwater Fisheries Laboratory of the Ministry of Agriculture, Fisheries and Food has developed a standard method for testing the toxicity of pesticides to fish. It determines toxicities for manufacturers in connexion with the data which have to be submitted under the Notification Scheme. The Laboratory's work has shown that the 'non-active' constituents of formulations cannot be disregarded, as some in themselves are relatively toxic to fish. It is clearly important that standard measurements of toxicity to fish should be made on all new pesticides as they appear.

(h) Effects of Spray Drift

130. Damage to crops from the drift of chemical sprays has always been a possibility. In the past the hazard was of relatively minor importance, but the appearance of the biologically very active growth regulator ('hormone') type herbicides has brought new problems of phytotoxicity, in particular that of damage to certain horticultural crops in the vicinity of sprayed areas.

131. Hazards to operators are controlled by regulations and recommendations for safe use. Hazards to bystanders and passers-by, referred to in paragraphs 47 and 48, are small when spraying or dusting is properly carried out. Experience has shown that such risks can be satisfactorily avoided by adequate supervision, instruction and education, and no problems of research are involved. Hazards to consumers of crops from neighbouring fields, or of hedgerow crops such as blackberries, have been thought to occur, when spray has drifted from the field of application. In the several instances which were brought to our attention, and which had been adequately investigated (with chemical analysis for residues of the pesticide used), we were satisfied that normal drift would not lead to a hazard to the consumer. This would not necessarily be the case, if the hedgerows themselves were sprayed with a highly toxic chemical.

132. On the other hand, damage to horticultural crops from spray drift has been difficult to control in practice and has been the subject of considerable study by a Government Committee. The drift from herbicides of the growth regulator type, even in very small quantities, may damage a variety of crops by causing malformation of leaves and fruit, with consequent loss of crop. Tomatoes have suffered most, but lettuce, chrysanthemums and some other crops have also been damaged. This has raised financial and legal problems which are outside the scope of our enquiry.

133. Damage of this kind is due mainly to lack of appreciation of the very active biological effects these herbicides may have at exceedingly low concentrations; to incorrect or careless use of equipment; or to inadequate regard to the weather conditions prevailing at the time of spraying, particularly direction and strength of wind. Practical instructions on how to avoid or reduce drift are contained in the booklet 'Code of Practice for Ground Spraying', issued by the Ministry of Agriculture, Fisheries and Food.

134. Various research aspects of this problem are being dealt with by a technical committee set up by the Agricultural Research Council. They include the better recognition of symptoms of herbicide damage and more accurate estimation of its magnitude. A considerable amount of work has already been done on diagnosis of damage, but the publication of the results in a form useful to growers is itself a problem, because of the fine differences between the symptoms of spray damage and those of other disorders, especially virus diseases. Research also continues on improvements in spraying techniques and equipment and on the physics of application, for example, the significance of droplet size.

135. Aerial spraying could increase dangers from spray drift. However, work at the National Institute of Agricultural Engineering has shown how the amount of drift from low-flying aircraft can be reduced to 1 per cent of the spray. It is thus possible that, with proper precautions, the risk of damaging crops downwind may be substantially reduced. Meantime, a Code of Conduct for aerial spraying, drawn up in consultation with Government Departments, has been published by the National Association of Agricultural Contractors.

136. There is still need for more information on such matters as optimum speeds and heights of flight for different types of machines, and for better means of producing sprays of uniform droplet size, both for ground and aerial spraying. Research already in progress on these problems should be intensified.

IX. RECOMMENDATIONS

137. Our review of the evidence has shown that research is in progress throughout our very wide field, and that no important aspect appears to have been entirely neglected. Nevertheless, there are parts of the field in which present research is not, in our opinion, commensurate with the need. Before discussing these, we wish to emphasise the importance of non-chemical methods of controlling pests. Good husbandry (including proper rotations and cultivations, dates of sowing, spacing of crops and general farm hygiene) will itself do much to limit the multiplication of weeds, diseases and pests. Chemicals provide a very potent, and often an essential, reinforcement, but the continuation of the best cultural practices and, in particular, their development in the light of accumulating biological knowledge, may reduce the amount of pesticides needed for efficient agricultural production. Our terms of reference, however, restrict us to the consideration of the effects of the use of toxic chemicals.

138. We have divided research problems into two groups, namely:

I. subjects of fundamental importance which, by their nature, preclude our making detailed and useful recommendations for further work, and

II. subjects on which specific recommendations are made.

Under each heading we add examples or explanatory notes.

GROUP I

139. Very considerable research has been, is being and will continue to be, devoted to most of the subjects detailed below. We are unable, at present, to

select from the general body of this work any limited projects for special support. We recommend that the work be kept constantly in review by the authorities responsible for it, and urge that whenever it appears that progress would be significantly advanced by the allocation of more support, either in equipment or manpower, such support should be readily forthcoming.

139.1. *The mode of action of pesticides on living organisms, as a basis for the search for less toxic and more selective chemicals, especially insecticides*

Since the basis of selective pesticidal action usually lies in a difference between the biochemical processes of the pest and of other organisms exposed to the pesticide, studies in comparative biochemistry are of fundamental importance. The empirical screening of new chemicals for biological activity is most suitably left to industry, as it is, for example, in the pharmaceutical field.

139.2. *The breeding of resistant varieties of crops*

The development of varieties resistant to pests and diseases may be a means of limiting the use of toxic chemicals. The introduction of varieties with a high degree of resistance to harmful biological factors has long been practised and has achieved noteworthy success in many cases. Current research includes the study of resistance in raspberries to the aphid vector of certain virus diseases, of apple varieties resistant to woolly aphid, and of resistance in black currants to the black currant gall mite. There are many other problems of this kind, to which the ideal solution would be the development of pest-resistant varieties; for instance, the development of a variety of sugar beet resistant to virus yellows would render unnecessary the present extensive spraying of this crop with insecticides.

139.3. *The basic nature of acquired resistance of pests to pesticides*

Steadily increasing numbers of insect species are developing resistance to the chemicals previously successfully used to control them. The development of resistance in some instances may be related to the indiscriminate use of a pesticide. New chemicals, which will attack the pests by different routes, are not always available and in the meantime the control of the resistant species may require the use of yet more toxic chemicals. Much has been done on the basic mechanism of resistance but, until this work has gone very much further, it will not be possible to plan the synthesis of new chemicals to replace those that have ceased to be effective.

139.4. *The mammalian toxicity, both chronic and acute, of chemicals used as pesticides*

The fundamental importance of studies on this subject is self-evident. Industry is compelled to make adequate studies of the toxicity of its products to mammals before they are cleared under the Notification Scheme for use as pesticides. Fundamental research in the field of toxicology is supported by the Medical Research Council.

139.5. *Studies on the biology, habits and life histories of the main species of wild birds and mammals, including population studies and studies of 'natural' mortalities*

A major difficulty in the investigation of some of the cases of mortality of birds and mammals in the field has been lack of knowledge of the habits and the circumstances of natural death of the various species. We believe there is opportunity for much further research on these subjects, some of which might be of interest to university departments of zoology.

139.6. *Studies on the biology and interdependence of animals, plants, insects and other organisms*

Any accurate appraisal of the effects of pesticides on wild life, including soil organisms, can only be made against a background of information on the biology, habits and life histories of the species concerned. Knowledge of the interdependence of animals, plants and insects will also enable better predictions to be made about the possible effects of applying a pesticide with a known and perhaps specific effect on certain plants and animals. The stimulus to work in these fields of fundamental study is not so strong as in the case of the subjects listed in the preceding paragraphs, but lack of knowledge of the biology of particular organisms has often been a cause of delay in applied research.

139.7. *Repellents for birds, bees and beneficial insects and attractants for harmful insects*

Repellents (to reduce the chances of birds or beneficial insects coming into contact with poisons) and attractants (to lure pests into traps containing suitable poisons) would have obvious advantages. Despite extensive search for repellents, little progress has been made and at present no promising line of attack has been found. A scientific approach is needed, rather than trial-and-error methods. As a result of more systematic investigation, some success has been achieved in the field of attractants.

GROUP II

140. Research to a greater or less degree is in progress on the subjects listed below, but on all of them we consider that intensified effort is needed. This work is of a kind which could readily be done, if more manpower and facilities were made available. The figures in parentheses refer to the relevant paragraphs in the body of the Report.

140.1. *Examination of hazards to which operators may be exposed*

Users of agricultural chemicals in the field are protected by statutory measures and also by the recommendations, issued by Government Departments, for the safe handling and use of toxic chemicals. These often involve the wearing of impermeable garments for difficult operations, under trying climatic conditions, with the understandable result that, on occasion, operators may disregard both the directions and the statutory requirements, which were drawn up at a time when little scientific evidence existed on the particular hazards involved. Confirmation is needed that these measures are neither insufficient nor excessive. New techniques (such as the placing of granules containing very toxic chemicals in or on the soil by machinery) are constantly being developed and it is necessary to determine by appropriate field studies the protection required by operators. These studies should include hazards to operators applying pesticides for the protection of stored products. (para. 42)

140.2. *Development of new and improved methods of analysis for residues of pesticides and their metabolites in plants and animals*

Reliable and sensitive physical, chemical and biological methods, of general application, for identifying and measuring the amounts of individual pesticides or their breakdown products are fundamental requirements for many aspects of pesticide work. We recommend:

1. intensification of the investigation of methods for the 'clean-up' (that is, the removal of interfering substances) and isolation of pesticide residues from plant and animal tissues;

2. further investigation of methods for identifying pesticides in the isolated fractions; methods such as gas-liquid chromatography, paper chromatography, infra-red spectrography, polarography and X-ray fluorimetry may all be of value;

3. further work on sensitive practical methods for the determination of amounts of residue isolated. (paras, 68, 101)

140.3. *Determination of residues in foodstuffs, including raw and processed commodities, both home-grown and imported*

We recommend that residue data should be obtained from appropriate trials carried out by the official agricultural advisory services and other official organisations. These trials are designed to obtain early information about biological efficiency when a product is to be submitted for official approval under the Agricultural Chemicals Approval Scheme. Such data could be used, in conjunction with those supplied by the manufacturer, when considering the draft recommendations on the safe use of a chemical. (para. 64)

We recommend, also, that selective surveys should be carried out of the amounts of residues occurring where pesticides have been applied in commercial practice. We understand that preliminary surveys of this nature have already been made of the presence of lead on apples, mercury in tomatoes and arsenic on potatoes, and we consider that these surveys should be extended to other foodstuffs including, for instance, brussels sprouts and beans after the use of organophosphorus insecticides. The residues may vary appreciably in amount according to the season and it would therefore be desirable to continue each survey for several years. We particularly recommend that such selective surveys should be carried out on imported foodstuffs. (para. 65)

140.4. *Investigation of the effects of pesticides on farm animals (including poultry)*

We recommend that more extensive trials should be carried out on the effects of feeding grain, treated wth liquid mercurial seed dressings, to farm animals, including poultry, both as regards the health of the animals themselves and the possible contamination of their flesh and products, such as eggs. (para. 76)

140.5. *Investigation into the need for using pesticides, into ways of using minimum amounts, and on spray drift*

We recommend that research be intensified on:

1. measures leading to the use of smaller amounts of chemicals, to give effective control of pests and diseases, the work to include studies of minimum levels of deposit required, distribution of deposits, activity of different types of deposits, the nature of plant surfaces and its influence on deposition and absorption, and the formulation of pesticides; (para. 56)

2. forecasting the incidence of pests and relating the results to the need to use chemicals against them; (para. 121)

3. problems of spray drift due to ground and aerial application of pesticides. (para. 136)

140.6. *Research into the persistence of pesticides and their breakdown products in the soil*

We recommend that research should include:

1. assessment of the extent to which active pesticide residues have already built up in soils in Great Britain, where routine pest control measures have been regularly applied; (para. 120)

2. investigation of the effects of pesticide residues on the growth and chemical composition of subsequent crops, including problems of taint and phytotoxicity; (para. 117)

3. investigation of the extent to which these residues modify soil flora and fauna and the fertility of the soil. (para. 119)

In these recommendations we have in mind the organo-chlorine insecticides, such as BHC, DDT, aldrin and dieldrin, and certain herbicides, which are not readily broken down in the soil, and the special problem posed by the indiscriminate use of persistent insecticides in fertiliser mixtures. (para. 117)

140.7. *Investigation of the possible contamination of water by pesticides, in particular aquatic herbicides and algicides, as affecting potable water and aquatic wild life*

We recommend that:

1. a limited investigation should be made to determine whether the use of pesticides leads to the contamination of potable water supplies; (para. 125)

2. research should be extended on side-effects from the use of chemicals to control water weeds; (para. 128)

3. standard measurements of the toxicity of pesticides to fish should be extended to include all new pesticides as they appear. (para. 129)

140.8. *Investigation of the effects of pesticides on wild life*

We recommend:

1. A study of the effects of BHC and other chemicals used in seed dressings on wild life generally, and correlation of the amounts found in the tissues with dosages of the chemicals ingested; (para. 95)

2. investigation of the 'pick-up' of organo-chlorine and other insecticides by worms, slugs, snails and other invertebrates in or on soil to which these chemicals have been applied, and of the effects of this on birds and mammals which consume them; (para. 91)

3. development of techniques for conducting surveys or enquiries into incidents reported from the field, including methods for accurately assessing bird mortalities; (para. 99)

4. investigations of mortalities of birds and animals, utilising full post-mortem and analytical chemical facilities. (para. 101)

140.9. *Investigation of methods of avoiding harm from toxic chemicals to bees*

We recommend:

1. search for control measures which avoid spraying during the flowering period of plants; (para. 110.1)

2. research into techniques for assessing the toxicity of chemicals to bees, both in the laboratory and in the field; (para. 110.2)

3. research on methods of detection and determination of pesticides in poisoned bees. (para. 110.3)

We have already referred to the desirability of having effective bee repellents. (para. 111)

140.10. *Studies on beneficial insects, on predator-pest relationships and on the timing of spray applications to reduce harm to beneficial insects*

We recommend that this work should include the assessment of the toxicity of chemicals to predators, the evaluation of chemicals known to possess a selective action in favour of predators, and a study of the relationships between predators and prey. Insufficient is known about the habits of most parasites and predators and it is, therefore, impossible to predict whether harmful effects will follow the introduction of new chemicals. (paras. 86, 87)

X. INITIATION AND CO-ORDINATION OF RESEARCH

141. The recommendations for further research made in the previous chapter involve (*a*) fundamental and applied research, for the conduct of which the Research Councils are the main Government agencies; and (*b*) selective surveys and operational research, normally conducted by Government Departments in discharge of their obligations and advisory functions in relation to the control of pesticides.

142. Recommendations for further research on subjects of the first kind will have to be considered by the Research Councils, in consultation with the office of the Minister for Science. These Councils are: the Agricultural Research Council, the Medical Research Council, the Council for Scientific and Industrial Research and the Nature Conservancy. They already have research stations where work of the kind suggested could suitably be carried out—indeed, most of the proposals are for an intensification of work already in progress—and the Nature Conservancy is in process of creating a station, one section of which will be specifically devoted to studying the effects of toxic chemicals on wild life.

143. Our recommendations for further fundamental research touch the interests of several of the Research Councils. We hope there will be periodic consultations between these Councils to keep in review the research being done under the aegis of each, especially that relating to the interactions between pesticide use and wild life. It would be helpful if the societies concerned with the protection of wild life could be brought into consultation in matters of this kind. Further, there would be considerable advantage in bringing in the Secretariat of the Scientific Subcommittee on Poisonous Substances used in Agriculture and Food Storage, to ensure that the results of researches carried out in the research institutes are available to, and applied in the work of, the Advisory Committee and its Scientific Subcommittee. This would provide a ready means for bringing forward, for discussion by research workers, problems arising from the continually changing use of pesticides in practice, which often come first to the notice of the Advisory Committee.

144. Our recommendations for further research on subjects of the second kind (for example, testing analytical methods, undertaking residue surveys and surveys of wild life deaths) concern essentially the development and expansion

of work already being undertaken to a limited extent by Government Departments. The three establishments mainly concerned at present are the Plant Pathology Laboratory and the Infestation Control Laboratory of the Ministry of Agriculture, Fisheries and Food, and the Laboratory of the Government Chemist, Department of Scientific and Industrial Research. Only the last-named has so far recruited staff for some expansion of this work.

145. We have considered carefully whether the implementation of the Group's recommendations demands the creation of some new co-ordinating or supervising committee, but have concluded it is not necessary. Fundamental and applied research is already catered for by the Research Councils and, for the fact-finding research needed as a basis for efficient administrative action by Government Departments, we have concluded that the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage and its Subcommittee could do all that is required.

146. Almost all problems arising from the practical use of pesticides come, at a very early stage, before the Advisory Committee, on which the four Research Councils are represented. We think it should be a function of the Advisory Committee to consider the needs for research on these problems as they arise and to bring these needs to the attention of the appropriate Research Councils or Government Departments, leaving it to them to decide how best to carry out the work. The Advisory Committee will be helped in its task by its Scientific Subcommittee, which is in a good position to appreciate where more information is needed.

147. The Scientific Subcommittee has special panels to advise on particular problems—for example, there is an analytical panel and a wild life panel—and further panels could be set up at any time. Its Secretariat already attempts to keep abreast of relevant research, but in view of its onerous duties under the Notification Scheme, it cannot at present cover the whole field.

148. We recognise that implementation of our proposals must lead to additions to the staffs of certain of the research institutes, including the projected new research station of the Nature Conservancy, and also to the staffs of the Ministry of Agriculture, Fisheries and Food's Plant Pathology Laboratory and Infestation Control Laboratory, both of which are responsible for certain aspects of pesticide work. The Secretariats of the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage and its Scientific Subcommittee will also need to be strengthened.

XI. SUMMARY

149. We summarise our study, and the main conclusions we have arrived at, as follows:

1. There is need for more knowledge of the effects of toxic chemicals used in agriculture and food storage, though we consider that some of the fears expressed about these effects have little foundation.

2. Administrative and voluntary action taken since the appearance of the three Reports of the Zuckerman Working Party has been generally successful in ensuring the safe use of pesticides. It was clear to us, however, that the regulations and administrative measures designed to achieve this, and to protect consumers of treated produce, are very imperfectly known.

3. The great majority of chemicals used as fungicides, insecticides and herbicides on farms and in orchards are valuable aids in food production and have no apparent deleterious effects on wild life. Unfortunately, however, there are a few chemicals which have had serious effects on birds and other wild life.

4. Experience in the use of pesticides often brings to light matters on which knowledge is inadequate, and the introduction of new chemicals and new methods of control is continually changing the position. The maintenance and extension of research, both fundamental and applied, is therefore essential. We have indicated where research work is now being done and have found that no important aspect is entirely neglected.

5. We have listed the chemicals used at the present time. Much effort is devoted, especially by industrial firms, to seeking safer chemicals to replace the more toxic ones and some success has already been achieved.

6. We have discussed the evidence received in relation to hazards to users of these chemicals, to consumers of treated crops, to farm livestock and to all forms of wild life.

7. We consider that hazards to users are minimal if the regulations laid down or recommendations made are properly observed, and relatively little further research in this direction seems called for.

8. We have received no evidence of harm to consumers of crops or food treated with pesticides. Official recommendations for the safe use of pesticides are so framed that any residues in food should be far below any dose liable to harm the consumer. Nevertheless, we recommend that further selective survey work should be undertaken to determine pesticide residues in food, both home produced and imported. This should serve as a check on whether official recommendations concerning the application of pesticides are being properly observed in practice.

9. We have reviewed in some detail the sequence of events concerned in the recent widespread deaths of birds and other wild life, due to the introduction of aldrin, dieldrin and heptachlor as seed dressings. We consider that certainty with regard to the effects of new pesticides on wild life cannot always be obtained by experimental trials and that some effects may become apparent only after the materials have been widely used in practice. We welcome the agreement recently negotiated between the Ministry of Agriculture, Fisheries and Food, industry and interested organisations, for the withdrawal of the three chemicals mentioned from use in seed dressings for spring-sown corn. We have concluded that there is need for more research workers to study various aspects of the effect of pesticides on wild life.

10. In Chapter IX we give our recommendations for research, in two groups. One group includes problems of fundamental importance, on which research is already in progress. The other group covers particular problems, on which we make recommendations in general terms, with illustrative or specific examples.

11. We have carefully considered whether a new body should be set up, to co-ordinate the continuing and expanding research which is required, but have

concluded that it is not necessary. This is because the Research Councils already cater for fundamental and applied research, while the Advisory Committee on Poisonous Substances used in Agriculture and Food Storage is in a position to keep Government Departments informed on the important fact-finding research being undertaken, or needed, in connexion with the safe use of pesticides.

12. We realise that implementation of our proposals will require additions to the staffs of certain of the research institutes and to those of the scientific laboratories of the Ministry of Agriculture, Fisheries and Food concerned with pesticides, as well as to the Secretariats serving the Advisory Committee and its Scientific Subcommittee.

150. We are happy to record our great indebtedness to Dr. E. J. Miller, our Secretary, and to Mr. N. K. Smith who, from October 1960, assisted him. Dr. Miller has extensive knowledge of the chemicals with which we were concerned and of the safeguards necessary for their use. Mr. Smith has a wide knowledge of the subject generally and of the manufacturing industry in particular. Their excellent and sustained work has been invaluable, both in the assembling of data and in the preparation of this Report. The valuable assistance given by Mr. R. F. Giles on administrative and legislative aspects has been greatly appreciated by the Group.

SIGNED *Chairman* H. G. SANDERS

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Dated: 29th September, 1961

APPENDIX A

Organisations which provided evidence

The Animal Health Trust
*The Association of British Manufacturers of Agricultural Chemicals
*The Association of Public Analysts
*The Botanical Society of the British Isles
The British Baking Industries Research Association
The British Bee-Keepers' Association
*The British Ecological Society
*The British Food Manufacturing Industries Research Association
The British Trust for Ornithology
*The Council for Nature
*The Country Landowners' Association
*The Food Manufacturers' Federation, Inc.
The Game Research Association
The Honey Producers' Association
*The Institute of Biology
*The National Association of Corn and Agricultural Merchants
The National Farmers' Union of England and Wales
The National Federation of Anglers
The National Federation of Women's Institutes
*The National Union of Agricultural Workers
*The Nature Conservancy
The Research Association of British Flour-Millers
*The Royal Entomological Society of London
The Royal Society for the Prevention of Cruelty to Animals
*The Royal Society for the Protection of Birds
*The Society of Medical Officers of Health
*The Soil Association
The Transport and General Workers' Union

Individuals who contributed evidence or information

F. C. Bawden, Esq., M.A., F.R.S., Rothamsted Experimental Station
Professor G. E. Blackman, M.A., F.R.S., Unit of Experimental Agronomy, Oxford
C. G. Butler, Esq., Ph.D., Rothamsted Experimental Station
R. J. Courshee, Esq., B.Sc., National Institute of Agricultural Engineering
G. H. L. Dicker, Esq., Ph.D., East Malling Research Station
E. F. Edson, Esq., O.B.E., M.Sc., M.B., Ch.B., Chesterford Park Research Station
H. C. Gough, Esq., B.Sc., Ph.D., D.I.C., National Agricultural Advisory Service, Cambridge

* Organisations which gave both written and oral evidence; the other organisations gave written evidence only.

F. H. Jacob, Esq., M.Sc., Plant Pathology Laboratory, Harpenden
A. R. Jennings, Esq., M.A., School of Veterinary Medicine, University of Cambridge
Professor H. G. H. Kearns, O.B.E., B.Sc., Ph.D., Long Ashton Research Station
A. H. M. Kirby, Esq., M.Sc., Ph.D., A.R.I.C., East Malling Research Station
W. S. S. Ladell, Esq., M.B., B.Ch., Chemical Defence Experimental Establishment, Porton
E. C. Large, Esq., B.Sc., F.R.I.C., Plant Pathology Laboratory, Harpenden
J. T. Martin, Esq., D.Sc., Ph.D., F.R.I.C., Long Ashton Research Station
J. L. McGirr, Esq., B.Sc., M.R.C.V.S., Central Veterinary Laboratory, Ministry of Agriculture, Fisheries and Food
P. S. Milne, Esq., B.Sc., National Agricultural Advisory Service, Harpenden
Professor J. W. Munro, C.B.E., D.Sc., Sunninghill
E. A. Parkin, Esq., D.Sc., Pest Infestation Laboratory, Slough
F. T. K. Pentelow, Esq., M.A., Fisheries Department, Ministry of Agriculture, Fisheries and Food
C. Potter, Esq., D.Sc., D.I.C., Rothamsted Experimental Station
W. H. Read, Esq., M.Sc., Glasshouse Crops Research Institute
B. C. Saunders, Esq., M.A., University of Cambridge
A. H. Strickland, Esq., M.A., Plant Pathology Laboratory, Harpenden
Professor R. L. Wain, D.Sc., F.R.S., Wye College, University of London.
M. J. Way, Esq., M.A., Imperial College Field Station, Silwood Park
H. Amphlett Williams, Esq., Ph.D., Public Analyst for the City and Port of London
E. K. Woodford, Esq., O.B.E., M.Sc., Ph.D., Weed Research Organisation, Oxford
D. W. Wright, Esq., M.A., National Vegetable Research Station, Wellesbourne.

Organisations who had no collective view to offer, or whose views were covered by the evidence of associated organisations

The Association of British Chemical Manufacturers
The Association of British Sheep and Cattle Dip Manufacturers
The British Chemical and Dyestuffs Traders Association
The British Medical Association
The British Field Sports Society
The Chemical Society
The Fruit and Vegetable Preservation Research Association
The Gamekeepers' Association of the United Kingdom
The Industrial Pest Control Association
The Medical Practitioners' Union
The National Association of Agricultural Contractors
The Society for Analytical Chemistry
The Trades Union Congress

APPENDIX B

Pesticides used in the United Kingdom

The list which follows contains the names of 153 pesticides, all of which are currently commercially available in this country (September, 1961). The various copper compounds, and the organo-mercury compounds used as fungicides, are each recorded as one in the list.

Although pesticides do not conveniently fall into a small number of easily definable groups, a grouping based on chemical type has been attempted, as follows:

1. organo-phosphorus compounds
2. dinitrophenol compounds
3. organo-chlorine (chlorinated hydrocarbon) compounds:
   - 3.1. endrin type
   - 3.2. DDT type
   - 3.3. chlorbenside type
   - 3.4. others
4. halogenated organic acids, salts and derivatives:
   - 4.1. growth regulator ('hormone') type
   - 4.2. others
5. organo-mercury compounds
6. substituted urea and carbamate compounds
7. heterocyclic compounds
8. naturally occurring and related compounds
9. antibiotics
10. miscellaneous organic compounds
11. miscellaneous inorganic compounds

The names given in *column 1* of the list are either British Standard Recommended Common Names for Pesticides (B.S. 1831:1961) or the chemical names as given in Appendix B (Pesticide Chemicals not requiring Common Names) to that Standard. The former are prefixed by BS, the latter by an asterisk. Otherwise, registered trade names or other names in common use are given, the chemical names assigned to them being in accordance with the nomenclature recommended by The Chemical Society, London.

The main function of each pesticide is given in *column 2*, using the following classification:

A = acaricide	I = insecticide
B = bactericide	I(v) = insecticide for veterinary use
F = fungicide	M = molluscicide
Gr = growth regulator	N = nematicide
H = herbicide	R = rodenticide (including other animal pests)

Column 3 indicates, by 'A', whether products containing the pesticide have been approved under the Agricultural Chemicals Approval Scheme (Appendix F). In *column 4* the letter R indicates that the chemical is controlled under the Agriculture (Poisonous Substances) Regulations 1956 to 1961.

Column 5 indicates whether or not the chemical is included in the dossier of official recommendations for the safe use of chemicals in agriculture and food storage, issued by the Ministry of Agriculture, Fisheries and Food on behalf of Government Departments. An entry in parenthesis indicates that a dossier sheet is in preparation.

	(1)	(2) *Use*	(3) *Approved*	(4) *Regulations*	(5) *Dossier*
1.	ORGANO-PHOSPHORUS COMPOUNDS				
BS	azinphos-methyl	1; A	'A'	R	Yes
BS	coumaphos	I(v)			
	'Delnav' [1, 4-dioxan-2, 3-ylidene *SS*-bis-(*OO*-diethyl phosphorodithioate).]	I(v)			
BS	demeton	I; A		R	Yes
BS	demeton-methyl	I; A	'A'	R	Yes
BS	diazinon	I; A	'A'		Yes
BS	dimefox	I; A	'A'	R	Yes
BS	dimethoate	I; A	'A'		Yes
BS	ethion	A		R	Yes
BS	fenchlorphos	I; I(v)			Yes
BS	malathion	I; A	'A'		Yes
BS	mecarbam	I; A	'A'	R	Yes
BS	mevinphos	I	'A'	R	Yes
BS	morphothion	I	'A'		Yes
BS	parathion	I; A	'A'	R	(Yes)
BS	phenkapton	A	'A'	R	Yes
BS	phosphamidon	I; A		R	Yes
BS	schradan	I; A	'A'	R	Yes
BS	sulfotep	I; A		R	(Yes)
BS	TEPP (HETP)	I	'A'	R	(Yes)
BS	trichlorphon	I; I(v)			Yes
2.	DINITROPHENOL COMPOUNDS				
BS	dinex	H			
BS	dinocap	F	'A'		
BS	dinosam	H			
BS	dinoseb	H	'A'	R*	Yes
BS	DNOC	H; I; A	'A'	R*	Yes
3.	ORGANO-CHLORINE COMPOUNDS				
3.1.	*endrin type*				
BS	aldrin	I; I(v)	'A'		Yes
BS	chlordane	I			
BS	dieldrin	I; I(v)	'A'		Yes
BS	endosulfan	I; A		R	Yes
BS	endrin	I; A	'A'	R	Yes
BS	heptachlor	I	'A'		
3.2.	*DDT type*				
BS	chlorobenzilate	A			Yes
BS	DDT	I; I(v)	'A'		
	'Kelthane' [2, 2, 2-trichloro-1, 1-di-(4-chlorophenyl) ethanol]	A	'A'		
BS	methoxychlor	I			
	'Rhothane' [1, 1-dichloro-2, 2-di-(4-chlorophenyl) ethane]	I	'A'		

* *Note*: Only concentrates containing more than 5 per cent dinoseb or DNOC are regulated.

	(1)	(2) *Use*	(3) *Approved*	(4) *Regulations*	(5) *Dossier*
3.3.	*chlorbenside type*				
	'Animert' [2, 4, 5, 4'-tetrachloro-diphenyl sulphide]	A			Yes
BS	chlorbenside	A	'A'		
BS	chlorfenson	A	'A'		
BS	fenson	A	'A'		
	'Tedion' [2, 4, 5, 4'-tetrachloro-diphenyl sulphone]	A			Yes
3.4.	*others*				
BS	BHC	I; I(v)	'A'		
BS	gamma-BHC	I	'A'		
*	carbon tetrachloride	I			(Yes)
	'DD' Mixture	N; I	'A'		
*	[1, 2-dichloropropane and				
*	1, 3-dichloropropene]				
*	p-dichlorobenzene	I			
	hexachlorobenzene	F			
*	ethylene dibromide	N; I			(Yes)
*	ethylene dichloride	I			
*	methyl bromide	N; I; R			
*	tetrachloroethane	I			
BS	toxaphene	I			
4.	HALOGENATED ORGANIC ACIDS, SALTS AND DERIVATIVES				
4.1.	*growth regulator ('hormone') type*				
BS	4-CPA	H			
BS	2, 4-D	H	'A'		
BS	2, 4-DB	H	'A'		
BS	dichlorprop	H			Yes
BS	fenoprop	H			
BS	MCPA	H	'A'		
BS	MCPB	H	'A'		
BS	mecoprop	H	'A'		Yes
*	α-naphthaleneacetic acid (NAA)	Gr	'A'		
	naphthoxyacetic acid	Gr			
BS	2, 4, 5-T	H	'A'		
	2, 4, 5-TB	H			
4.2.	*others*				
BS	dalapon	H	'A'		(Yes)
BS	2, 4-DES	H			
*	fluoroacetamide	I; R	'A'	R	Yes
*	monochloroacetic acid	H			
*	sodium fluoroacetate (see Footnote)	R			
*	trichloroacetic acid (TCA)	H	'A'		
*	2, 3, 6-trichlorobenzoic acid (TBA)	H	'A'		

Footnote: The sale and use of monofluoroacetic acid and its salts is rigorously controlled under the Poisons Regulations.

	(1)	(2) *Use*	(3) *Approved*	(4) *Regulations*	(5) *Dossier*
5.	ORGANO-MERCURY COMPOUNDS. Various organo-mercury compounds, with mercury as the toxic agent, are used as fungicides in the following forms:—				
	1. dry seed dressings	F	'A'		Yes
	2. liquid seed dressings	F	'A'		(Yes)
	3. sprays	F	'A'		Yes
	4. aerosols	F		R	Yes
	5. dips	F			
6.	SUBSTITUTED UREA AND CARBAMATE COMPOUNDS				
BS	antu	R			
BS	chlorpropham	H	'A'		
BS	diuron	H			
BS	fenuron	H			
BS	ferbam	F			
BS	maneb	F	'A'		
BS	metham-sodium	H; I; F; N	'A'		Yes
	zineb-polyethylenethiuram disulphide complex	F			Yes
BS	monuron	H			Yes
BS	nabam	F	'A'		
BS	propham	H			
	'Sevin' [1-naphthyl-*N*-methylcarbamate]	I; I(v)	'A'		Yes
BS	thiram	F; R	'A'		
BS	zineb	F	'A'		
BS	ziram	F			
7.	HETEROCYCLIC COMPOUNDS				
*	aminotriazole	H	'A'		Yes
	anthraquinone	R			
BS	atrazine	H			Yes
BS	captan	F	'A'		
BS	coumachlor	R			
	chloralose	R			
BS	diquat-dibromide	H	'A'		Yes
BS	endothal-sodium	H		R	Yes
*	maleic hydrazide	Gr			Yes
BS	simazine	H	'A'		Yes
BS	warfarin	R			
8.	NATURALLY OCCURRING AND RELATED COMPOUNDS				
	derris	I	'A'		
*	(mixture of rotenone and related compounds)				
	gibberellic acid	Gr			
*	nicotine	I	'A'		
*	pyrethrins	I; I(v)			
	quassia	I			
	red squill	R			
	ryania	I			
*	strychnine (see Footnote)	R			

Footnote: The sale and use of strychnine is rigorously controlled under the Poisons Regulations.

	(1)	(2) *Use*	(3) *Approved*	(4) *Regulations*	(5) *Dossier*
9.	ANTIBIOTICS				
BS	griseofulvin	F			Yes
BS	oxytetracycline	B			Yes
BS	streptomycin	B			Yes
10.	MISCELLANEOUS ORGANIC COMPOUNDS				
*	azobenzene	A	'A'		
*	carbon disulphide	I			
*	chloranil	F			
*	chloropicrin	N; I			
	cresylic acid	H	'A'		
BS	dichlone	F			
BS	dicloran	F	'A'		Yes
BS	dodine acetate	F	'A'		Yes
*	formaldehyde	F	'A'		
*	metaldehyde	M	'A'		
*	naphthalene	I			
*	nonanol	Gr			Yes
	organic thiocyanates	I; A	'A'		
*	pentachlorophenol	H	'A'		
	petroleum oils	I; A; H	'A'		
*	2-phenylphenol	F			
BS	proxan-sodium	H			
BS	quintozene	F	'A'		
*	salicylanilide	F			
	tar oils	I	'A'		
BS	tecnazene	F	'A'		
	xylenol	N			
11.	MISCELLANEOUS INORGANIC CHEMICALS				
	arsenous oxide	R			
	barium carbonate	R			
*	barium silicofluoride	I; R			
	borax [sodium tetraborate]	H			
*	calcium arsenate	I			
*	copper acetoarsenite	M; I			
	copper compounds used as fungicides (including basic carbonate and sulphate, oxychloride, 8-quinolinate, cuprammonium carbonate, cuprous oxide)	F	'A'		
	cyanide powders	R			
*	hydrogen cyanide	I; R			
*	lead arsenate	I	'A'		Yes
*	lime sulphur	F; A; I	'A'		
*	mercuric chloride	F			
*	mercurous chloride (calomel)	F; I	'A'		
	phosphorus (red)	R			
*	potassium cyanate	H			
*	sodium chlorate	H	'A'		
*	sodium fluoride	I			
*	sodium silicofluoride	I			
*	sulphur	F	'A'		
*	sulphuric acid	H			
*	zinc phosphide	R			