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USE OF PESTICIDES

A REPORT OF

THE PRESIDENT'S SCIENCE ADVISORY COMMITTEE

THE WHITE HOUSE

WASHINGTON, D.C.

May 15, 1963

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STATEMENT OF THE PRESIDENT

This report on the use of pesticides has been prepared for me by my Science Advisory Committee.

I have already requested the responsible agencies to implement the recommendations in the report, including the preparation of legislative and technical proposals which I shall submit to the Congress.

Because of its general public interest, I am releasing the report for publication.

John F. Kennedy

THE WHITE HOUSE,
May 15, 1963

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I. INTRODUCTION

Man's primary concerns have always been the struggle for survival and improvement of his lot. As his numbers increased, he attained greater ability to manipulate his environment. In the process he sometimes inflicted damage on himself and on his surroundings. Advances have always entailed a degree of risk which society must weigh and either accept, or reject, as the price of material progress.

A major step in civilization was the domestication of food plants. With the birth of organized agriculture and the resultant concentration of crops and animals, the stage was set for outbreaks of pests. Until that time man had to search for food as did the pests. Afterward neither had to search; instead, pest control became necessary. The welfare of an increasing human population requires intensified agriculture. This in turn enables the pests to increase, which necessitates the use of pesticides with their concomitant hazards. It thus seems inevitable that, as the population increases, so do certain hazards.

In an effort to understand and evaluate these problems, the Panel undertook a review of the information relevant to pesticides, including experimental data and the various administrative procedures which are designed for the protection of the public. The Panel could not have accomplished this review without the assistance it received from the Departments of Agriculture, Interior, Defense, and Health, Education, and Welfare, as well as from many individuals throughout the country.

The information provided to the Panel has demonstrated how remarkably effective the modern organic chemicals are in facilitating both the control of insect vectors of disease and the unprecedented production of food, feed, and fiber. The use of pesticides associated with the production of our food is carefully controlled by the growers and supervised by agricultural specialists and the Food and Drug Administration. As a result, the residue levels measured on foods intended for interstate and foreign commerce are low and rarely above Federal tolerance limits.

The Panel believes that the use of pesticides must be continued if we are to maintain the advantages now resulting from the work of informed food producers and those responsible for control of disease. On the other hand, it has now become clear that the proper usage is not simple and that, while they destroy harmful insects and plants, pesticides may also be toxic to beneficial plants and animals, including man. Their toxic effects in large doses are well known and precautions can be taken to see that humans are

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never needlessly exposed. But we must now also take measures to insure that continued exposures to small amounts of these chemicals in our environment will not be harmful over long periods of time.

Review of pesticides brings into focus their great merits while suggesting that there are apparent risks. This is the nature of the dilemma that confronts the Nation. The Panel has attempted to state the case—the benefits, the hazards, and the methods of controlling the hazards. It can suggest ways of avoiding or lessening the hazards, but in the end society must decide, and to do so it must obtain adequate information on which to base its judgments. The decision is an uncomfortable one which can never be final but must be constantly in flux as circumstances change and knowledge increases.

II. GAINS FROM THE USE OF PESTICIDES

Our material standard of living has been greatly elevated during the 20th century by increased control over the environment. Few recent developments have been so effective or have had application in such a wide range of human endeavor as the pesticide chemicals. Although pesticides have been used for centuries as adjuncts in pest control, the great advances of the last 20 years resulting from the discovery, manufacture, and application of new compounds have changed their role in many instances to that of the principal and, frequently, sole control measure.

Pesticides have made a great impact by facilitating the production and protection of food, feed, and fiber in greater quantity and quality; by improving health; and by keeping in check many kinds of nuisance insects and unwanted plants. Agricultural needs have entailed the largest applications of pesticides in this country. Productivity has been so increased that famine is an unknown experience to the people of the developed nations. Mechanization, improved fertilizers, and the breeding of productive and disease-resistant crops have also contributed importantly. In addition, pesticides have made possible the economical production of many crops which otherwise would be available only to a limited number of wealthy consumers.

While reducing food losses, pest control has also resulted in foodstuffs of the highest quality. Today, for example, sweet corn, potatoes, cabbage, apples, and tomatoes are all available unmarred, and the American housewife is accustomed to blemish-free products. Citrus fruits are seldom damaged or lost because of scale insects, fruitflies, or diseases, and the cost of animal protein is lower because large losses of cattle from tick fever and grubs no longer occur.

Modern agricultural efficiency is maintained not only through the use of insecticides, but also by means of herbicides, fungicides, rodenticides, nematocides, plant-growth regulators, and other chemicals. Their benefits extend beyond crops raised for direct human consumption. They permit efficient production of forage and grains, which in turn are needed

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for a productive livestock economy. In addition, they allow profitable yields of nonfood crops such as cotton, tobacco, and timber. Pesticides have not, however, reached an optimum of effectiveness. More than 100 established pests have developed resistance to one or more previously effective chemicals, and new pests are occasionally introduced by international traffic.

Rapid population growth and concomitant decrease in land available for agriculture necessitate greater crop yields per acre and reduction of losses and spoilage in stored foods. Moreover, many products must be protected during the process of manufacture and distribution.

Besides enabling spectacular increases in agricultural production, pesticides have freed man from communicable diseases to an unprecedented extent. In less developed areas of the world, malaria, typhus, and yellow fever, previously controlled only with great difficulty, are now limited and in some locations eradicated. In each case, pesticides have facilitated control of the insect vector. At some stage of their natural history a number of the major communicable diseases involve an intermediate host or vector. Most successful disease-control programs have been directed at eliminating this link in the chain of transmission, rather than treating man after he has contracted the disease.

However, control programs have not achieved disease eradication. Malaria is still the disease responsible for the largest number of deaths in the world each year, although new cases are rare in the United States. Yellow fever, schistosomiasis, plague, and some rickettsial diseases are almost unknown in the mainland of North America, but they still take a large toll of human lives in the rest of the world. Furthermore, reservoirs of disease in animals, and insects which can transmit them, will remain with us for the predictable future both in this country and in other parts of the world, thus requiring a continued effort to control them.

An additional complication in disease control is that the insect vectors, such as mosquitoes that transmit malaria, may produce resistant populations capable of transmitting their resistance to pesticides from generation to generation. In order to keep up with the successive threats of insect vectors as they develop resistance to one chemical after another, it is important to enlarge and improve our capability for controlling pests.

Pesticides also have made control of many nuisance insects and plants financially feasible. Were the cost higher, the funds for their control would be used by other more critical demands on the economy. For example, it might be too expensive to control the varieties of mosquitoes that breed in marshes and estuaries which do not transmit disease, but limit man's enjoyment of some of the most desirable recreational areas. Similarly, elimination of roaches from kitchens, aphids from roses, and fungi from golf greens are very desirable but nonessential benefits.

Efficient agricultural production, protection of health, and elimination of nuisances are now required and expected by modern man. The methods

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used to accomplish these ends must continue to improve, although their present scope and magnitude far exceed the few examples included here. It is certain that coming years will witness sophistication of methods and new uses for which pesticides were not originally conceived.

III. THE HAZARDS OF USING PESTICIDES

Evidence of increasing environmental contamination by pesticide chemicals has generated concern which is no longer limited to citizens of affected areas or members of special-interest groups. During two decades of intensive technical and industrial advancement we have dispersed a huge volume of synthetic compounds, both intentionally and inadvertently. Many, such as detergents, industrial wastes, and pesticides, are now found far from the point of initial dispersal.

Today, pesticides are detectable in many food items, in some clothing, in man and animals, and in various parts of our natural surroundings. Carried from one locality to another by air currents, water runoff, or living organisms (either directly or indirectly through extended food chains), pesticides have traveled great distances and some of them have persisted for long periods of time. Although they remain in small quantities, their variety, toxicity, and persistence are affecting biological systems in nature and may eventually affect human health. The benefits of these substances are apparent. We are now beginning to evaluate some of their less obvious effects and potential risks.

Precisely because pesticide chemicals are designed to kill or metabolically upset some living target organism, they are potentially dangerous to other living organisms. Most of them are highly toxic in concentrated amounts, and in unfortunate instances they have caused illness and death of people and wildlife. Although acute human poisoning is a measurable and, in some cases, a significant hazard, it is relatively easy to identify and control by comparison with potential, low-level chronic toxicity which has been observed in experimental animals.

The Panel is convinced that we must understand more completely the properties of these chemicals and determine their long-term impact on biological systems, including man. The Panel's recommendations are directed toward these needs, and toward more judicious use of pesticides or alternate methods of pest control, in an effort to minimize risks and maximize gains. They are offered with the full recognition that pesticides constitute only one facet of the general problem of environmental pollution, but with the conviction that the hazards resulting from their use dictate rapid strengthening of interim measures until such time as we have realized a comprehensive program for controlling environmental pollution.

A. Classes of Compounds

The term pesticide broadly includes compounds intended for a variety of purposes. They are used to control insects, mites, ticks, fungi, nematodes,

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rodents, pest birds, predatory animals, rough fish, plant diseases, and weeds; and also to act as regulators of plant growth, as defoliants, and as desiccants. As of June 1962, almost 500 compounds incorporated in more than 54,000 formulations were registered for use in the United States.

1. The chlorinated hydrocarbons containing carbon, hydrogen, and chlorine are the pesticides used in greatest tonnage. The most familiar are DDT, dieldrin, aldrin, endrin, toxaphene, lindane, methoxychlor, chlordane, and heptachlor. Among those used extensively as herbicides are 2,4-D and 2,4,5-T for control of broad-leaved weeds in lawns, pastures, cereal crops, and brush growth along highways and fences.

2. The organic phosphorus compounds, composed of phosphorus, oxygen, carbon, and hydrogen, are used principally as insecticides and miticides. Parathion, malathion, phosdrin, and tetraethyl pyrophosphate (TEPP) are examples.

3. Other organic compounds include the carbamates, dinitrophenols, organic sulfur compounds, organic mercurials, and such natural products as rotenone, pyrethrum, nicotine, strychnine, and the anticoagulant rodent poisons.

4. Inorganic substances with a long history of use include copper sulfate, arsenate of lead, calcium arsenate, compounds of chlorine and fluorine, zinc phosphide, thallium sulfate, and sodium fluoroacetate.

B. Distribution and Persistence in the Environment

The worldwide use of pesticides has substantially increased since the development of DDT and other chlorinated hydrocarbons in the early 1940's. United States production and use are illustrated in figures 1 and 2. It is estimated that 350 million pounds of insecticides alone were used in the United States during 1962. They are distributed annually over nearly 90 million acres (about 1 acre out of 20 within the 48 contiguous States). These acreages are composed of farmlands, forests, and insect-breeding areas, including wetlands. Weedkillers are distributed on approximately the same number of acres, with some overlap of areas covered by insecticides. Thus the land area treated with pesticides is approximately 1 acre of 12 within the 48 States. About 45 million pounds are used each year in urban areas and around homes, much of this by individual homeowners. The annual sale of aerosol "bug bombs" amounts to more than one per household. Other compounds, such as fungicides, also are used in substantial tonnage.

In recent years we have recognized the wide distribution and persistence of DDT. It has been detected at great distances from the place of application and its concentration in certain living organisms has been observed. DDT has been found in oil of fish that live far at sea and in fish caught off the coasts of eastern and western North America, South America, Europe, and Asia. Observed concentrations have varied from less than 1 part per million (ppm) to more than 300 ppm in oil.

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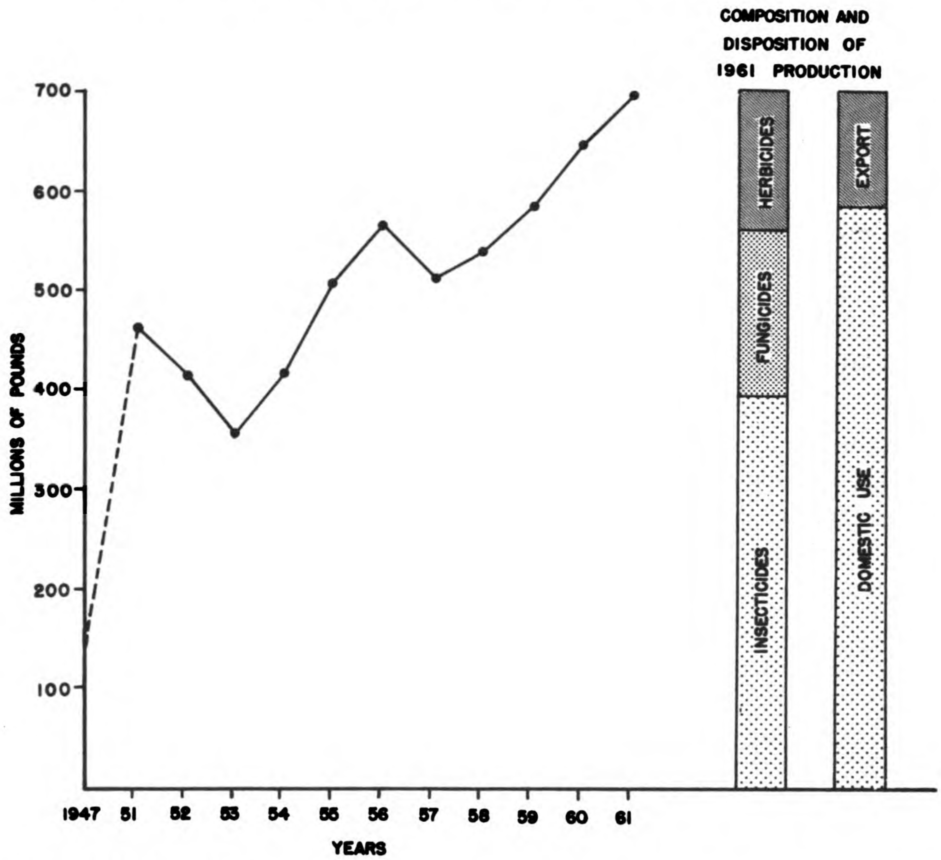
U.S. Production of Synthetic Organic Pesticides



Source: USDA, 1962.

Figure 1

Residues of DDT and certain other chlorinated hydrocarbons have been detected in most of our major rivers, in ground water, in fish from our fresh waters, in migratory birds, in wild mammals, and in shellfish. Small amounts of DDT have been detected in food from many parts of the world, including processed dairy products from the United States, Europe, and South America. The amounts are rarely above Food and Drug Administration (FDA) tolerance limits, but these have probably contributed to the buildup of DDT we now observe in the fat of the people of the United States, Canada, Germany, and England. In the United States, DDT and its metabolites have been found in the fat of persons without occupational exposure at an average of 12 ppm (approximately 100 to 200 mg. of DDT per adult) for the past 10 years. In England and Germany, recent studies revealed an average concentration of 2 ppm in human fat. Data about children are not available.

An important characteristic of several commonly used pesticides is their persistence in the environment in toxic form. The chemical half life of stable chlorinated hydrocarbons in soils, and the time they remain active against some soil insects, are measured in years. The organic phosphorus

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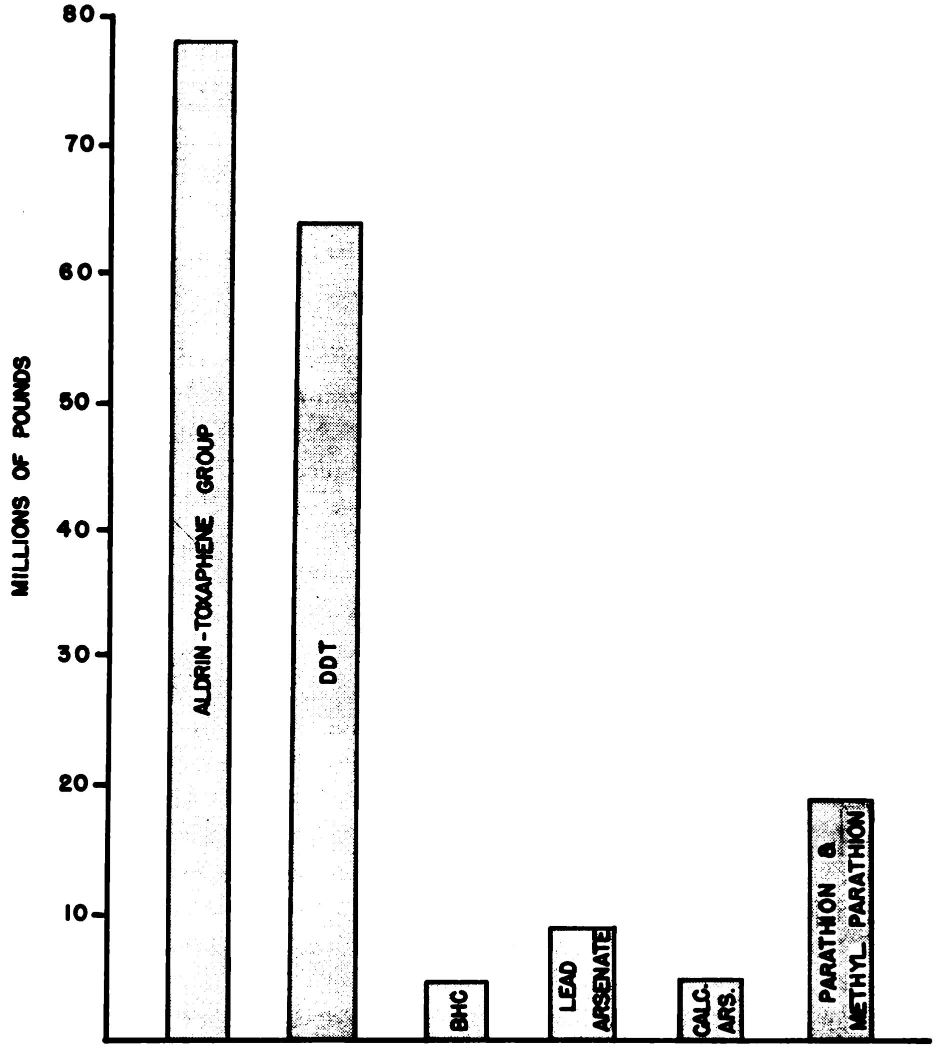

FIGURE 2

compounds are more rapidly degraded although, under certain circumstances, they have persisted from one growing season to the next following routine application. Pyrethrum, rotenone, and nicotine are destroyed relatively rapidly after application, but compounds incorporating copper, lead, and arsenic are persistent.

The distribution and persistence of other chlorinated hydrocarbons have been studied in less detail, although some of these chemicals have been widely applied. One of these, dieldrin, resembles DDT in stability, persistence, and in solubility. Recently, it has been found in the fat of residents of southern England. It has also been found in many wild birds, fish, and mammals in the United States. These facts led the Panel to anticipate that surveys will discover dieldrin and other persistent chlorinated hydrocarbons in man and wildlife throughout most of the United States.

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C. Biological Effects on Man and Animals

1. Exposure of man

The extent of hazard associated with use of a pesticide is determined by the degree of exposure and the compound's toxicity. Exposure depends on persistence, the amount applied, the method of application, and availability of the chemical in a biologically active form. Pesticides can enter the body by (*a*) ingestion, (*b*) absorption through the intact skin, and (*c*) inhalation.

(*a*) When examining the potential hazards to man from extensive use of pesticides, an early consideration should be the possible effects of chemical residues in the Nation's food supply. The Panel has received evidence that, before pesticides are recommended for registration, considerable research has been performed on the extent and nature of their residues on foods, and that safeguards exist which can permit pesticide usage without danger to the consumer. These include proper controls over manufacture, commercial distribution, and techniques of pesticide application to crops; strict establishment of tolerance limitations; inspection for residues in produce; and other precautions. When measured in foods entering interstate or foreign commerce, and in total diet studies, residue levels have been very low and rarely above the legal tolerance limits. If illegal residues are found, the foods containing them are removed from the market.

Residues are not so consistently low for food items marketed within their State of origin. Some State authorities sample food for pesticide residues. Data from certain States have shown residues well above the Federal tolerance on 3 percent of the fresh fruits and vegetables offered for sale in wholesale markets. Many States do not perform systematic sampling for residues in the produce and dairy products intended for consumption within the State.

Residues of several chlorinated hydrocarbons have been measured in game birds and game fish at levels above Federal tolerance limits. Because few wildlife meals are consumed, this is not an important source for residue accumulation in man. By contrast, household use of pesticides with inadvertent contamination of dishes, utensils, or food may well produce more significant residues in man.

(*b*) Most insecticides are readily absorbed through the intact skin. Skin contamination can be an important source of exposure for persons who mishandle pesticides in their formulation or commercial application. Furthermore, since householders usually take few precautions in their home and garden uses of these chemicals, they may receive extensive skin contact both from successive applications and from continuing exposure to residues.

The rate of absorption through the skin depends on the chemical nature of the pesticide and on its formulation. In general, compounds in solution in oils or in organic solvents are absorbed more readily than those in aqueous preparations or in dry powder. Skin absorption can occur from

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pesticide aerosols, from dusts, from clothing or blankets impregnated with chlorinated hydrocarbons, and from contaminated soil or lawn grass.

The rates of skin absorption have not been adequately studied in man. It is particularly important to determine the rates at which mothproofing insecticides are absorbed through human skin in contact with impregnated clothing or blankets. Such impregnation is performed during the manufacture of mothproofed garments and materials, and routinely during dry-cleaning. Many of these articles, such as sweaters and blankets, may be in direct contact with the skin for prolonged periods. Clearly, studies are needed to understand possible sensitization and allergic responses.

(*c*) Man's exposure to pesticides ~~can also occur~~ through inhalation. Airborne insecticides are sources of exposure when released during fogging operations directed against nuisance insects in public areas, buildings, and homes. Pesticides may be inhaled in dusts from treated soil, from house dusts contaminated by applications for household pests, or from mothproofed rugs and blankets.

2. *Effects on man*

There have been few systematic studies of people occupationally exposed to pesticides. In one such investigation, a small group of volunteers with an intake up to 35 mg. of DDT per day over a period of months was reported to show no apparent ill effects during 18 months of gross observation. DDT and its metabolites averaged 270 ppm in their fat, more than 20 times the average level found in adults sampled in this country. Limited groups of adults occupationally exposed to the more toxic pesticides are also being studied, and there is evidence of neurologic impairment, usually reversible, in those individuals heavily exposed to certain chlorinated hydrocarbons and organic phosphates. Unfortunately, possible long-term effects of other compounds cannot be predicted on the basis of experience with DDT, or even predicted for DDT itself, on the basis of the limited clinical studies available.

Accidental acute poisoning in man has been caused by about 50 pesticides, including at least 1 compound from each major class. Each year, approximately 150 deaths are attributed to misuse of pesticides in the United States. About half of these occur in children who were accidentally exposed at home. The number of nonfatal poisonings can only be estimated. A Special Committee on Public Policy Regarding Agricultural Chemicals, appointed by Gov. Edmund G. Brown on June 15, 1960, reported that in California, which uses 20 percent of the nationally consumed pesticides, 3,000 children per year ingest various amounts of these compounds. In that State during 1959 there were also 1,100 cases of occupational disease due to agriculture chemicals, mostly among agricultural workers. These figures include acute illnesses, whether the reaction was very mild, or severe enough to require hospitalization. One difficulty in estimating the incidence of poisoning is that the symptoms caused by pesticide toxicity are little different from those of many common illnesses.

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Little is known about the consequences to man when he accumulates more than one pesticide in his body. Synergism, or potentiation, is the joint action of two agents which results in an effect which is greater than the sum of their individual effects. Some combinations of two organic phosphates have produced effects 10 times those observed when either compound was fed separately. Preliminary FDA data show only additive effects from mixtures of chlorinated hydrocarbons included in diets of experimental animals.

Physicians are generally unaware of the wide distribution of pesticides, their toxicity, and their possible effects on human health. Diagnosis of pesticide toxicity is apparent when a patient with acute asthma has to be resuscitated in the middle of the night following exposure to commercial fogging. However, diagnosis is difficult in patients with nonspecific symptoms that may result from unsuspected contamination with pesticides. The Panel was unable to find any federally sponsored research in this area of potential medical importance.

3. *Effects on wildlife*

Many kinds of insect-control programs have produced substantial mortalities among birds and other wildlife. Some fatalities have been the result of carelessness or nondirected use; others have followed programs carried out exactly as planned. Mortalities among birds have approached 80 percent in areas heavily treated with DDT for Dutch elm disease control, with heptachlor for imported fire ant control, and with aldrin or dieldrin for controlling the Japanese beetle. Fish losses have been extensive even with lower rates of application in programs such as spruce budworm control using DDT. Losses following agricultural operations are more scattered and less well documented.

Most insecticides are toxic to a wide range of animals, and certain classes are consistently more susceptible than others. Insecticides tend to be more toxic to invertebrates than vertebrates, because the target insects are more closely related to other invertebrates. For example, pink shrimp have been experimentally poisoned by 0.9 parts per billion of heptachlor. Other marine organisms are also highly sensitive. The growth of young oysters has been inhibited by concentrations as low as 3 parts per 100 million of chlordane, heptachlor, or rotenone. Five other commonly used pesticides inhibit oyster growth in concentrations of 1 part per 10 million.

An entire year's production of young salmon was nearly eliminated in the Miramichi River in New Brunswick in 1954, and again in 1956. This resulted from DDT applications of one-half pound per acre for control of the spruce budworm. Stream insects, which are a most important food for young salmon, disappeared and failed to return within 2 years. Surviving young salmon were very thin. In British Columbia, mortality of coho salmon approached 100 percent in at least four major streams after the surrounding forests were sprayed with 1 pound of DDT per acre for control

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of the black-headed budworm. This mortality occurred despite preventive measures to avoid treating the streams themselves.

Among vertebrates, fish are generally more sensitive than birds, and birds are more sensitive than mammals. Reptiles and amphibians vary greatly from species to species, but their susceptibilities usually fall between those of fish and birds. Variations in sensitivity may result in the elimination of certain forms from the food chain. While some organisms may be decimated, resistant organisms which survive exposure may concentrate and store pesticides at levels higher than those found in the environment. Such biological magnification on the part of resistant species may ultimately damage more sensitive organisms which are higher in the food chain. At Clear Lake, Calif., for example, waters containing 0.02 ppm of TDE produced plankton containing 5 ppm, which in turn produced fish with fat containing hundreds to thousands of parts per million. Grebes that fed on the fish died although their fat contained somewhat smaller residues than the fish.

Robin populations declined drastically after Dutch elm disease spraying in certain communities in Wisconsin and Michigan. Earthworms, resistant to DDT, fed on fallen elm leaves and accumulated substantial amounts of the pesticide. Robins, for whom worms are a principal food, fed on the worms and died.

The process of biological magnification has less impact on man because human food is produced by a two- or three-link chain in which the process, if recognized, can be controlled. For example, residues are permitted on feeds for domestic animals only in amounts that will not ultimately yield unacceptable levels in meat, in milk, or in other animal products. Thus, excessive levels of pesticide residues in agricultural products used for human food result only from accident or misuse, while damaging levels in the food of wild animals may be unwanted effects resulting from recommended practices. When contaminated fish and shellfish are harvested commercially, any residues they may contain are of concern to the fisherman and the consumer. Yet the commercial fisherman cannot control the sources of such contamination.

Wild animal populations are affected differently by pesticides residues than are domestic animals and man. Unlike the latter, wild animals cannot be kept from treated areas long enough for the chemical residues to degrade or otherwise dissipate. Because birds and mammals are free to range over relatively large areas, they are exposed to a variety of different compounds. Insectivorous birds are likely to be attracted to areas with dense insect populations, and may be exposed when chemicals are applied. Furthermore, birds reoccupy a depleted area very rapidly; thus a treated area may constitute a trap into which successive waves of birds move and are killed. Fish in streams are generally less mobile than birds and mammals, but they, too, may be subject to multiple exposure to pesticides.

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Flowing waters contaminated by accidental drifts or run-offs can affect the fish even though they do not move into treated areas.

D. Toxicity of Specific Compounds

1. Chlorinated hydrocarbons

In very small doses (some cases less than 1 ppm) chlorinated hydrocarbons have caused liver damage to experimental animals, and in large doses they have caused acute central nervous system effects, occasionally followed by death. The mechanisms leading to these effects are unknown.

The biological effects of DDT have been studied more fully than those of other pesticides. Its toxicity to man and other mammals is low. People ingesting large amounts of DDT usually suffer no apparent ill effects. In chronic feeding experiments with rats, 5 ppm produced characteristic chlorinated hydrocarbon changes in the liver, but no evidence of tumor induction. Reproduction studies in rats showed that 50 ppm reduced the number of young that survived the nursing period. There was no effect on reproduction at 10 ppm. However, many useful insects and other valuable invertebrates such as shrimp, crayfish, and crabs are highly susceptible to DDT. Decimation of these useful populations may be a costly side effect of extensive applications.

Dieldrin and aldrin are many times more toxic to vetebrates than DDT. Since aldrin is converted to dieldrin in man and in the environment, a discussion of dieldrin applies to both.

Dieldrin is present in the body fat of residents of England (average 0.2 ppm) and is probably also present in the fat of the U.S. population as a result of extensive applications of the chemical in this country. There have been many cases of acute poisoning in people exposed to dieldrin in their work. Signs of intoxication involve the central nervous system, and may include electroencephalographic changes, muscle tremors, and convulsions. Individuals have suffered recurrences of these symptoms after they have been free of them for more than a month following their last exposure.

Our knowledge of toxicity at lower doses comes chiefly from FDA feeding experiments in which mice were fed varying concentrations of dieldrin and aldrin in their diet. Chronic exposure to as little as 0.5 ppm produced histological liver damage while increase to 10 ppm caused a fourfold increase in the frequency of liver tumors. There are virtually no data on the effects on embryonic development. In one of the few experiments known to the Panel, the feeding of dieldrin (at 0.6 mg./kg. of body weight) to several pregnant dogs resulted in 100 percent mortality of 14 nursing puppies. The mothers were fed the pesticide during pregnancy but none during lactation. In another study, rats fed dieldrin at 2.5 ppm in the diet showed a significant reduction in number of pregnancies and an increased mortality in suckling young.

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Although most insecticides do not kill wild mammals in the field even when they kill birds and fish, 1 to 3 lbs. per acre of dieldrin or aldrin produces high mortality among mammals in the treated areas. Dieldrin is also highly toxic to many birds, amphibia, reptiles, and fish. It reduces the reproduction of captive quail by decreasing egg production, decreasing the percentage of eggs that hatch, and increasing the mortality of chicks. Many beneficial and useful invertebrates are very susceptible.

Other chlorinated hydrocarbons in common use have shown marked acute toxicity to rats in feeding experiments. Chronic effects have been noted with chlordane and heptachlor at the lowest level fed to experimental animals. Chlordane at 2.5 ppm produced liver damage and 0.5 ppm of heptachlor epoxide produced liver damage and increased mortality in the laboratory mice. Field use also suggests high toxicity to birds and mammals. Although these substances are used in large quantities, there have been no studies to determine whether they accumulate in the human population, nor are there adequate studies of their genetic, tumorigenic, teratogenic, or reproductive effects in mammals or birds.

2. Organic phosphorus compounds

Among their effects, the organic phosphorus compounds inhibit cholinesterase activity and thereby interfere with transmission of impulses from nerve to ganglion and nerve to muscle.

Most organic phosphorus insecticides have relatively high acute toxicities and have caused many fatal and nonfatal poisonings in man. In cases of poisoning, removal from exposure to the compound usually permits rapid recovery. Many of them are degraded rapidly and thus seldom persist in the environment, but some, such as parathion, have persisted for months in soils and have recently been found in trace amounts in water drawn from deep wells.

IV. PEST CONTROL WITHOUT CHEMICALS

Methods for controlling pests without the use of pesticides were known to farmers even in ancient times. Crops were planted in areas least liable to pest damage; crops were moved to virgin territory to leave the pests behind; rotation was practiced and crops that were less prone to disease were planted; if the pests came late in the season, crops were planted early, and vice versa. Many of these methods are used today.

The environment can also be modified indirectly; for example, we use screens on windows to keep out mosquitoes, and flood or drain marshes to destroy their breeding areas. In certain cases parasites, predators, and diseases control the pests without chemicals. In the United States and many other countries of the world parasites and predators have been successfully introduced to combat scale insects on citrus fruits, apples, and sugarcane; and in Australia the myxomatosis virus was introduced to kill rabbits.

Entomologists have long been interested in the use of insect enemies for pest control. The U.S. Department of Agriculture has been active in this

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area since 1888. It has imported more than 500 species of insect-destroying organisms, of which about 36 have had partial or complete success. Introduced insects have succeeded in controlling cactus in Australia and Klamath weed in the Western United States. However, biological methods of insect control have received relatively little attention in the United States by comparison with the great emphasis on chemical control.

An effective method of biological control is the discovery or breeding of resistant varieties of crops. This method has worked best for plant diseases, and several varieties of wheat which are resistant to rust have been bred in this country. Another example of the use of plant resistance was provided by the grafting of French wine grapes to resistant American rootstocks when the French grapes were severely damaged by the root insect *Phylloxera* in the middle of the last century.

Other examples of effective biological control can be cited, but success has not been frequent. Continued and extensive searches will undoubtedly yield more, and the Panel believes this approach should be expanded.

Although nonchemical methods for pest control are intriguing, they also have weaknesses. Two are particularly important. In the first place, parasites and predators have adjusted over the millenia to a dynamic balance with their hosts such that they kill some but not all of them; complete host destruction would eliminate the parasite or predator by destroying its food supply. Thus, control of the pest is seldom complete enough to prevent economic damage. Furthermore, reduction of the pest population is rarely sufficient to prevent its becoming dense again. A second limitation to the use of natural enemies is that the host may become resistant, just as it may develop resistance to chemical controls.

Australian rabbits, for example, are becoming resistant to myxomatosis, and their populations once again are on the increase.

A new method of biological control is the laboratory production of sterile male insects in very large numbers, using either gamma rays or specific chemical sterilants. The males are then liberated into the natural population where their matings produce infertile eggs. Although this procedure eliminated the screwworm fly in Florida, it has not yet been investigated extensively for controlling other insects.

A still newer method is the use of sex attractants to lure male insects into traps and thus to their death. With certain species this technique has great promise, and developmental research is being expanded.

The variety of methods that has proven useful for biological control of certain pests, and the indication of potential value for others, lead to the conclusion that more active exploration and use of these techniques may yield important benefits for the national economy and for the protection of health.

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V. THE ROLE OF GOVERNMENT IN PESTICIDE REGULATION

A. Mechanisms for Regulation

Public interest in the protection of the Nation's health and its resources has led to the enactment of legislation and the establishment of administrative procedures to regulate the marketing and use of pesticides. The Public Health Service has general responsibilities for the health of man and the Fish and Wildlife Service for the protection of wild animals. In addition, two fundamental laws, the Federal Insecticide, Fungicide, and Rodenticide Act, and the Food, Drug, and Cosmetic Act, assign responsibility for pesticide control to the U.S. Department of Agriculture (USDA) and responsibility for the safety of foods containing pesticide residues to the Department of Health, Education, and Welfare (HEW). The Secretary has delegated this responsibility to the Food and Drug Administration (FDA).

When a new pesticide is developed in an industrial laboratory an application is submitted to USDA requesting that it be registered for use. If the proposed use does not include application on a food crop, USDA reviews the experimental data submitted with the application. The compound is registered for use if it is concluded that no undue hazard to man and domestic animals is associated with the proposed use when applied according to the instructions on the label.

When a pesticide is proposed for use on food crops, the application for registration must list each crop on which it is to be applied and must present the necessary data on effectiveness and toxicity. If it can be demonstrated to USDA that the produce leaves no residue on a particular crop when used in the proposed manner, the specific pesticidal formulation covered by the application is registered for use on that crop on a "no residue" basis. The product may then be legally shipped in interstate commerce. If, however, the compound leaves a residue, USDA delays registration until a residue tolerance has been established by FDA.

To initiate this procedure, the manufacturer files a petition for tolerance with FDA. The USDA then certifies to FDA that the product under consideration is useful and offers an opinion on whether the petitioner's proposed tolerance reasonably reflects the residues to be expected from its use according to directions. Until 1955, tolerances were established by FDA on the basis of testimony presented in public hearings. Present law requires the petitioner to present FDA with experimental evidence on toxicity to establish what tolerances, if any, will be safe, to show that the tolerances can be met under the practical conditions of the pesticide use and to provide practical methods of analysis for enforcement of the tolerances.

The concept of "zero tolerance" should be distinguished from that of "no residue." "No residue" is a determination by USDA, based on experimental data, that none will remain from a particular pesticide use, irrespective of toxicity. "Zero tolerance" is an FDA prohibition of any residue on

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a crop because the compound is too toxic to permit a residue. The concepts of "zero tolerance" and the "no residue" registration have been modified as more sensitive detection methods became available. In practice, "zero tolerance" is interpreted by FDA in some cases to include a detectable level of residue, lower than that believed to be pharmacologically significant.

In addition to toxicity data, the petitioner must also submit information on the chemistry of the compound, reference to related uses, and residue measurements on the crop involved. If the raw agricultural product is to be used for animal feed, data must be submitted on residues in meat and milk. A method of analysis suitable for enforcement purposes also must be submitted.

When a tolerance has been set by FDA, USDA registers the pesticide which can then be marketed with approved labeling. No pesticide can be shipped in interstate and foreign commerce without USDA registration; however, by law USDA must grant registration "under protest" upon written demand of a petitioner subsequent to registration refusal by USDA. At present, the purchaser cannot distinguish such a product from one which has been accepted for registration because the label does not carry any indication of its unsanctioned status.

A pesticide registration must be renewed every 5 years. Within that interval petitioners may apply for increased tolerances or for extension of existing tolerances to additional crops. Similarly, FDA may alter residue tolerances if new information warrants. Lower tolerances are not set unless the FDA believes it could prove in court that the hazard is greater than formerly determined.

The Food and Drug Administration is responsible for establishing safe tolerances of pesticide residues on food products and for enforcing such tolerances by preventing illegal residues on interstate and foreign food shipments. The Department of Agriculture has sole responsibility for approving registration for pesticide use on any agricultural product other than food crops, on food crops where no residue results, and for all non-agricultural uses.

Both USDA and FDA have enforcement programs. The USDA is responsible for insuring that the marketed pesticides are properly labeled. The FDA is responsible for ensuring that tolerances are not exceeded. In addition, individual States may directly control pesticides uses, and enforce their own tolerances for produce sold within the State.

B. Adequacy of Pesticide Control

Federal laws and administrative practices relating to pesticides are intended to assure both efficacy of the product and safety to the purchaser, user, and the public. Decisions on efficacy appear to be based on reliable evidence. Experiments are well designed, meaningful controls are used, sample sizes are adequate, and conclusions reached are supported by the

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data obtained. However, efficacy alone is not an adequate criterion for judgment. Unless a pesticide proposed for registration is equally effective in a less hazardous way than methods already available, the Panel believes registration should be considered conservatively. As a corollary to cautious registration of new pesticides, more hazardous compounds might well be removed from the market when equally effective and less hazardous substitutes are found. The Panel believes that it is necessary to modify the use of some especially hazardous and persistent materials now registered.

The Panel has found that decisions on safety are not as well based as those on efficacy despite recent improvements in the procedures required by the Federal Food, Drug, and Cosmetic Act for the establishment of safe tolerances for pesticide residues on food. Until 1954, the evidence of safety was submitted in the form of testimony at public hearings, and tolerances were established when the evidence appeared to support the application. At that time, the manufacturer was not required to provide an analytical method for the practical enforcement of the tolerance. Moreover, FDA had no subpena power to require testimony not voluntarily offered. Amendments of the act in 1954 materially improved these procedures. In addition to requiring the submission of data on chemistry, toxicology, and residues, it also required the petitioner to provide a practical analytical method for use in enforcement. The result was the provision of more data from animal experiments and, in some cases, information on human pharmacology.

As an administrative principle, tolerances are set by FDA at 1/100 of the lowest level which causes effects in the most sensitive test animals whenever data on human toxicity are not available. However, tolerances have been set for some compounds such as dieldrin, aldrin, heptachlor (epoxide), and chlordane, although a "no effect" level in animals has never been determined. After reviewing the data on which tolerances are based, the Panel concludes that, in certain instances, the experimental evidence is inadequate. Recent review by FDA has also demonstrated several such examples and the tolerances are being reassessed.

The Panel believes that all data used as a basis for granting registration and establishing tolerances should be published, thus allowing the hypotheses and the validity and reliability of the data to be subjected to critical review by the public and the scientific community.

The FDA has responsibility only for setting tolerances for pesticides which remain on foods. Decisions on all the other uses of these compounds and registration for all other compounds are the responsibility of USDA. Thus the Department of Agriculture regulatory staff evaluates and approves uses that bring pesticides into intimate contact with people, such as mothproofing of clothes and blankets, and applications to households, lawns, and gardens. The Panel believes that decisions on registrations, clearly related to health, should be the responsibility of the Department of Health, Education, and Welfare.

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Current registration procedures are primarily intended to protect people and domestic animals from damage by pesticides. The protection of fish and wildlife resources will require affirmation of this intent by Congress. Following such action by the Congress, the Panel believes the Secretary of the Interior should actively participate in review of all registrations that may affect fish and wildlife.

Federally operated or supported programs are subject to review by the Federal Pest Control Review Board. In addition, an Interdepartmental Committee on Pest Control exchanges information regarding control programs. An Armed Forces Pest Control Board provides liaison and coordination within the Department of Defense and regulates sales of pesticides in military stores. There are no provisions for Federal control of use after sale except in Federal programs and by indirect means such as enforcement of residue tolerances.

The Federal Pest Control Review Board was established in 1961 through joint actions of the Secretaries of Agriculture, Interior, Defense, and Health, Education, and Welfare, and is composed of representatives from each of these departments. Technical matters are referred to staffs within the agencies for consideration and advice, and occasionally to the Interdepartmental Committee on Pest Control. The Board has not used consultants from outside the Government. The basic responsibility for Federal pest control operations is placed by statute in various departments and agencies. The fact that these same agencies constitute the Federal Pest Control Review Board restricts the Board's effectiveness in reviewing the programs of member agencies. The Board carefully considers programs before giving clearance and, when appropriate, offers recommendations for altering proposed procedures. Although many programs have been modified as a result of such reviews, particularly by the incorporation of additional safeguards, the discontinuation of a program has not been recommended.

More than half of the insecticides used in Federal programs are applied for the control of pests introduced from foreign areas. Quarantine is a first defense, but there are opportunities for pests to spread. Through prompt action, the Mediterranean fruitfly has been eradicated on three occasions during the last 33 years, following introduction into Florida. In these cases, prompt eradication of the fly prevented its spread and the need for more extensive use of chemicals.

Although eradication of a pest population is a laudable goal, it is seldom realistic. Control programs by contrast, apply pesticides in less volume, to a smaller land area, with fewer undesirable side effects at any one time, yet produce the same economic results. The gypsy moth, fire ant, Japanese beetle, and white-fringed beetle programs, which have been continued for years, are examples of failures of the "eradication" approach. The acceptance of a philosophy of control rather than eradication does not minimize the technical or economic importance of a program, but acknowledges the realities of biology. As new control techniques such as male sterilization

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or highly specific attractants are developed for practical use, the elimination of some of our alien pests may become technically and economically feasible.

In 1962, the Federal Government supported control programs involving the application of pesticides to more than 4 million acres, at a cost of about $20 million. Although the federally supported programs represent only a small part of the total national use of pesticides, individual programs may involve thousands of acres of populated urban areas.

The Panel feels that Federal programs should be models of correct practice for use in the guidance of States, localities, and private users. They should, therefore, be conducted not only with attention to maximum effect on the target organisms, but with further evaluation of the associated hazards. It would, in these terms, be reasonable to expect that every large-scale operation be followed by a complete report which would appear in the public literature.

VI. RECOMMENDATIONS

The Panel's recommendations are directed to an assessment of the levels of pesticides in man and his environment; to measures which will augment the safety of present practices; to needed research and the development of safer and more specific methods of pest control; to suggested amendments or public laws governing the use of pesticides; and to public education.

A. In order to determine current pesticide levels and their trends in man and his environment, it is recommended that the Department of Health, Education, and Welfare:

1. Develop a comprehensive data-gathering program so that the levels of pesticides can be determined in occupational workers, in individuals known to have been repeatedly exposed, and in a sample of the general population. As a minimum, the survey should include determinations on fat, brain, liver, and reproductive organs in adults and infants; examinations to determine if placental transmission occurs; and determination of levels which may be excreted in human milk. These studies should use samples sufficiently large and properly drawn to obtain a clear understanding of the manner in which these chemicals are absorbed and distributed in the human body.

2. Cooperate with other departments to develop a continuing network to monitor residue levels in air, water, soil, man, wildlife, and fish. The total diet studies on chlorinated hydrocarbons initiated by the Food and Drug Administration should be expanded. These should, for example, include data on organophosphates, herbicides, and the carbamates in populated areas where they are widely used.

3. Provide Federal funds to assist individual States to improve their capabilities for monitoring pesticide levels in foods which are produced and consumed within the state.

B. In order to augment the safety of present practices, it is recommended that:

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1. The Food and Drug Administration proceed as rapidly as possible with its current review of residue tolerances, and the experimental studies on which they are based. When this review is completed, it is recommended that the Secretary of Health, Education, and Welfare select a panel from nominations by the National Academy of Sciences to revaluate toxicological data on presently used pesticides to determine which, if any, current residue tolerances should be altered. Of the commonly used chemicals attention should be directed first to heptachlor, methoxychlor, dieldrin, aldrin, chlordane, lindane, and parathion because their tolerances were originally based upon data which are in particular need of review. Upholding the same standards, the Secretary should ensure that new compounds proposed for registration be rigorously evaluated.

2. The existing Federal advisory and coordinating mechanisms be critically assessed and revised as necessary to provide clear assignments of responsibility for control of pesticide use. The Panel feels that the present mechanisms are inadequate and that it is necessary to provide on a continuing basis for:—

(*a*) Review of present and proposed Federal control and eradication programs to determine if, after consideration of benefits and risks, some programs should be modified or terminated.

(*b*) Development and coordination of a monitoring program conducted by Federal agencies to obtain timely, systematic data on pesticide residues in the environment.

(*c*) Coordination of the research programs of those Federal agencies concerned with pesticides.

(*d*) Initiation of a broad educational program delineating the hazards of both recommended use and of the misuse of pesticides.

(*e*) Review of pesticide uses and, after hazard evaluation, restriction or disapproval for use on a basis of "reasonable doubt" of safety.

(*f*) A forum for appeal by interested parties.

3. The National Academy of Sciences-National Research Council be requested to study the technical issues involved in the concepts of "zero tolerance" and "no residue" with the purpose of suggesting legislative changes.

4. The Secretaries of Agriculture, Interior, and Health, Education, and Welfare review and define their roles in the registration of pesticides that are not present on food, but that may impinge on fish and wildlife or come into intimate contact with the public.

5. The accretion of residues in the environment be controlled by orderly reduction in the use of persistent pesticides.

As a first step, the various agencies of the Federal Government might restrict wide-scale use of persistent insecticides except for necessary control of disease vectors. The Federal agencies should exert their leadership to induce the States to take similar actions.

Elimination of the use of persistent toxic pesticides should be the goal.

C. Research needs:

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1. In order to develop safer, more specific controls of pests, it is recommended that Government-sponsored programs continue to shift their emphasis from research on broad spectrum chemicals to provide more support for research on—

(*a*) Selectively toxic chemicals.
(*b*) Nonpersistent chemicals.
(*c*) Selective methods of application.
(*d*) Nonchemical control methods such as the use of attractants and the prevention of reproduction.

In the past few years, the Department of Agriculture has shifted its programs toward these specific controls. The Panel believes this trend should be continued and strengthened. Production of safer, more specific, and less persistent pesticide chemicals is not an unreasonable goal, but its attainment will require extending research efforts beyond empirical approaches to more fundamental studies of subjects such as: the mode of action of pesticides; comparative toxicology; the metabolism of compounds in insects, plants, and higher animals; and the processes of chemical degradation and inactivation in nature. Such studies will also provide the information necessary to control those pests which are rapidly becoming resistant to currently available chemicals. Intensified effort is needed in the search for selective methods of pesticide application. Compounds are often applied in excessive quantity or frequency because of such inefficiencies as drift, uneven coverage, or distribution methods insufficiently specific to reach the target pest.

2. Toxicity studies related to man

The toxicity data upon which registrations and tolerances are based should be more complete and of higher quality. Although data are available on acute toxic effects in man, chronic effects are more readily demonstrated in animals because their generation time is shorter, and thus the natural history of pesticide effects is telescoped chronologically. However, there will continue to be uncertainties in the extrapolation from experimental animals to man, and in the prediction of the nature and frequency of effects in humans on the basis of those observed in other forms of life.

The Panel recommends that toxicity studies include determination of—

(*a*) Effects on reproduction through at least two generations in at least two species of warmblooded animals. Observations should include effects on fertility, size and weight of litter, fetal mortality, teratogenicity, growth and development of sucklings and weanlings.

(*b*) Chronic effects on organs of both immature and adult animals, with particular emphasis on tumorigenicity and other effects common to the class of compounds of which the test substance is a member.

(*c*) Possible synergism and potentiation of effects of commonly used pesticides with such commonly used drugs as sedatives, tranquilizers, analgesics, antihypertensive agents, and steroid hormones, which are administered over prolonged periods.

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3. Toxicity studies related to wildlife

The Panel recommends expanded research and evaluation by the Department of the Interior of the toxic effects of pesticides on wild vertebrates and invertebrates.

The study of wildlife presents a unique opportunity to discover the effects on the food chain of which each animal is a part, and to determine possible pathways through which accumulated and, in some cases, magnified pesticide residues can find their way directly or indirectly to wildlife and to man.

4. Amplification of research resources

Only by stimulating training and basic investigation in the fields of toxicology and ecology are research needs likely to be met. An increased output of basic research data and a continuing supply of capable research personnel could be ensured by a system of grants and contracts. Training grants, basic research grants, and contracts to universities and other nongovernmental research agencies funded by the Departments of Agriculture, Interior, and Health, Education, and Welfare would stimulate this research. In order to accelerate immediate progress, it might prove useful to explore the contributions which can be made by competent research people and their facilities in other countries.

D. In order to strengthen public laws on pesticides, it is recommended that amendments to public laws be requested. These should:

1. Eliminate "protest" registrations.

The Panel concurs with the Department of Agriculture that these technically evade the intent of the public laws. Industry needs an appeal mechanism, however, to protect it from arbitrary decisions. Public hearings could be held on such appeals.

2. Require that every pesticide formulation carry its official registration number on the label.

The Department of Agriculture has recommended such an amendment as a means of increasing the protection of the consumer.

3. Clarify the intent of the Federal Insecticide, Fungicide, and Rodenticide Act to protect fish and wildlife by including them as useful vertebrates and invertebrates.

4. Provide, as a part of the operating budgets of Federal control and eradication programs, funds to evaluate the efficiency of the programs and their effects on nontarget organisms in the environment. Results of these studies should be published promptly.

Approximately $20 million were allocated to pest control programs in 1962, but no funds were provided for concurrent field studies of effects on the environment. The Department of Agriculture has repeatedly suggested that other interested agencies participate in the control programs, but funds have not been available except by diversion from other essential agency functions.

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E. To enhance public awareness of pesticide benefits and hazards, it is recommended that the appropriate Federal departments and agencies initiate programs of public education describing the use and the toxic nature of pesticides. Public literature and the experiences of Panel members indicate that, until the publication of "Silent Spring" by Rachel Carson, people were generally unaware of the toxicity of pesticides. The Government should present this information to the public in a way that will make it aware of the dangers while recognizing the value of pesticides.

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