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USE OF PESTICIDES

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A REPORT OF

(THE) PRESIDENT'S SCIENCE ADVISORY COMMITTEE

THE WHITE HOUSE

WASHINGTON, D.C.

May 15, 1963

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price 15 cents

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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.

THE WHITE HOUSE,
May 15, 1963

TABLE OF CONTENTS

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 er; needlessly exposed. But we must now also take measures to insure t continued exposures to small amounts of these chemicals in our environ-nt will not be harmful over long periods of time.

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

II. GAINS FROM THE USE OF PESTICIDES

Our material standard of living has been greatly elevated during the h century by increased control over the environment. Few recent elopments have been so effective or have had application in such a de range of human endeavor as the pesticide chemicals. Although ticides have been used for centuries as adjuncts in pest control, the at advances of the last 20 years resulting from the discovery, manu-ture, and application of new compounds have changed their role in ny instances to that of the principal and, frequently, sole control measure. Pesticides have made a great impact by facilitating the production and otection of food, feed, and fiber in greater quantity and quality; by proving health; and by keeping in check many kinds of nuisance sects and unwanted plants. Agricultural needs have entailed the largest plications of pesticides in this country. Productivity has been so in-cased that famine is an unknown experience to the people of the de-loped nations. Mechanization, improved fertilizers, and the breeding f productive and disease-resistant crops have also contributed importantly. n addition, pesticides have made possible the economical production of any crops which otherwise would be available only to a limited number f wealthy consumers.

While reducing food losses, pest control has also resulted in foodstuffs f the highest quality. Today, for example, sweet corn, potatoes, cab-age, apples, and tomatoes are all available unmarred, and the American ousewife is accustomed to blemish-free products. Citrus fruits are eldom damaged or lost because of scale insects, fruitflies, or diseases, and he cost of animal protein is lower because large losses of cattle from tick ever 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, ematocides, plant-growth regulators, and other chemicals. Their bene-its extend beyond crops raised for direct human consumption. They ermit efficient production of forage and grains, which in turn are needed for a productive livestock economy. In addition, they allow produ... yields of nonfood crops such as cotton, tobacco, and timber. Pesti... have not, however, reached an optimum of effectiveness. More than ... established pests have developed resistance to one or more previously ef-fective chemicals, and new pests are occasionally introduced by int... tional traffic.

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

Besides enabling spectacular increases in agricultural production, pesti-cides 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 con-trol of the insect vector. At some stage of their natural history a num... of the major communicable diseases involve an intermediate host or v... Most successful disease-control programs have been directed at elim...ing this link in the chain of transmission, rather than treating man ...er he has contracted the disease.

However, control programs have not achieved disease eradication. Ma-laria 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 un-known 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 vec..., such as mosquitoes that transmit malaria, may produce resistant pop...tions 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 im-portant 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 ... in marshes and estuaries which do not transmit disease, but limit man's ...ment of some of the most desirable recreational areas. Similarly, el...tion of roaches from kitchens, aphids from roses, and fungi fr... greens are very desirable but nonessential benefits.

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

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

III. THE HAZARDS OF USING PESTICIDES

Evidence of increasing environmental contamination by pesticide chemi-als has generated concern which is no longer limited to citizens of affected reas or members of special-interest groups. During two decades of in-ensive technical and industrial advancement we have dispersed a huge olume of synthetic compounds, both intentionally and inadvertently. Many, such as detergents, industrial wastes, and pesticides, are now found ar 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, 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 51,000 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 famil[illegible] are DDT, dieldrin, aldrin, endrin, toxaphene, lindane, methoxych[illegible] chlordane, and heptachlor. Among those used extensively as herbi[illegible] 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 [illegible] poisons.

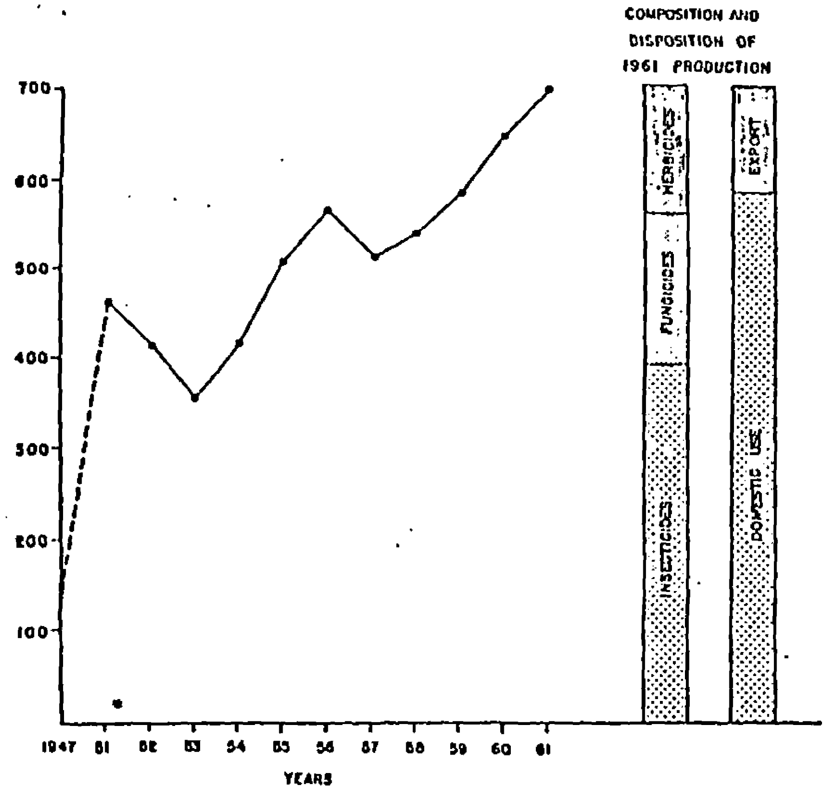
4. Inorganic substances with a long history of use include copper su[illegible] arsenate of lead, calcium arsenate, compounds of chlorine and flu[illegible] zinc phosphide, thallium sulfate, and sodium fluoroacetate.

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 [illegible] 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 [illegible] plication and its concentration in certain living organisms has b[illegible] served. DDT has been found in oil of fish that live far at sea and caught off the coasts of eastern and western North America, South A[illegible] Europe, and Asia. *Observed concentrations* have varied from le[illegible] part per million (ppm) to more than 300 ppm in oil.

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

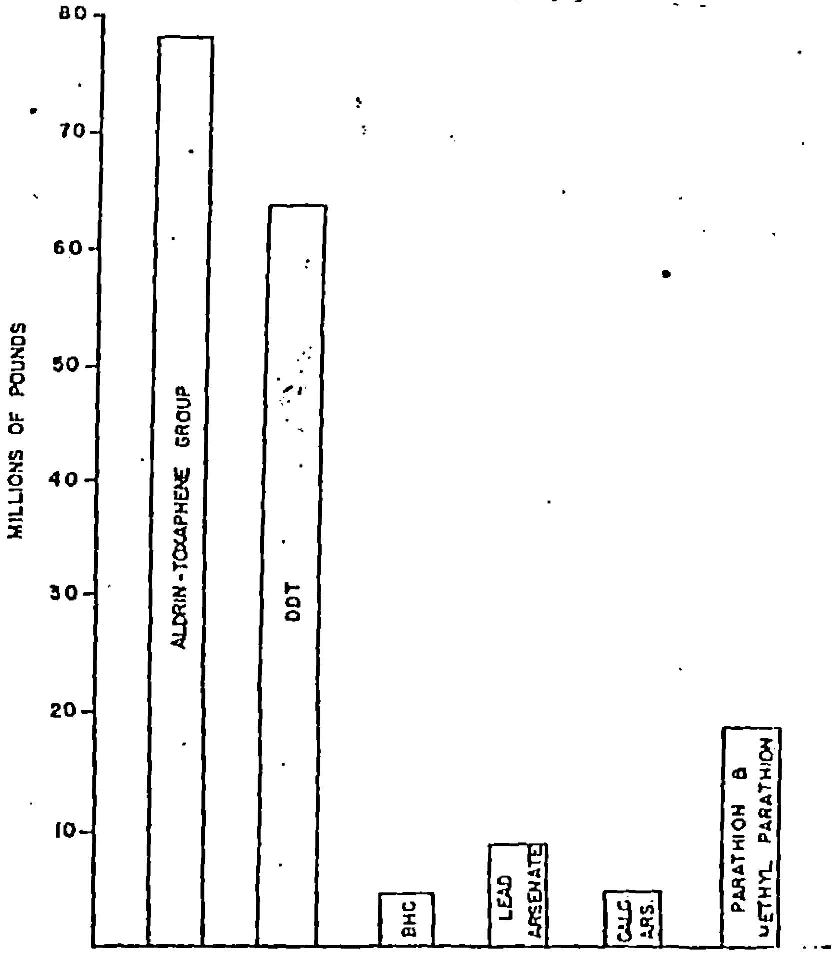


FIGURE 2

compounds are more rapidly degraded although, under certain ci... stances, they have persisted from one growing season to the next foll... routine application. Pyrethrum, rotenone, and nicotine are de... relatively rapidly after application, but compounds incorporating ... 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 anticip... that surveys will discover dieldrin and other persistent chlorinated hydr... ns in man and wildlife throughout most of the United States.

C. Biological Effects on Man and Animals

Exposure of man

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

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

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

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

(b) Most insecticides are readily absorbed through the intact skin. Skin ontamination 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 oth 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 n oils or in organic solvents are absorbed more readily than those in queous preparations or in dry powder. Skin absorption can occur from 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 poisoning are little different from those of many common illnesses.

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 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 TDD 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 sprays 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 pesticide 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 of 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.

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

D. Toxicity of Specific Compounds

hlorinated hydrocarbons

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

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

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

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

ur knowledge of toxicity at lower doses comes chiefly from FDA feeding riments in which mice were fed varying concentrations of dieldrin and n in their diet. Chronic exposure to as little as 0.5 ppm produced logical liver damage while increase to 10 ppm caused a fourfold ase in the frequency of liver tumors. There are virtually no data on the ts on embryonic development. In one of the few experiments known to 'anel, the feeding of dieldrin (at 0.6 mg./kg. of body weight) to several nant dogs resulted in 100 percent mortality of 14 nursing puppies. The iers were fed the pesticide during pregnancy but none during lactation. nother study, rats fed dieldrin at 2.5 ppm in the diet showed a signifi- reduction in number of pregnancies and an increased mortality in ling young.

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 thi