This issue of Utah Science is largely adapted from a seminar series entitled “Pesticides in Perspective” conducted during the winter academic quarter at Utah State University, January-March, 1971. The seminars were sponsored by the Departments of Veterinary Science and Zoology and the Inter-departmental Curriculum in Toxicology. At the conclusion of the series, Dr. K. W. Hill moderated a panel discussion of the topic with L. A. Jensen, D. M. Berry, G. E. Bohart, and I. Palmblad. The principal theme expressed by these panelists has been summarized into short essays while the general content or text of the seminar presentations appear in the other articles. The only articles in this issue which did not originate with the seminar series are the news and information items, the editorial and the stories by Mr. Hickman and Dr. Low.

It is the hope of the seminar participants that this issue, summarizing the seminar series, will help to clarify some aspect of the pesticide dilemma for our readers. Unquestionably, not all aspects have been explored in depth but such is the consequence of compressing such a large topic into this format.

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EDITORIAL—SOME CONSIDERATIONS

OUR JEKYLL AND HYDE
CHEMICAL WORLD

Pesticides have been the subject of research at USU for approximately 20 years. Most of the earliest work centered on the gross effects of these chemicals on domestic plants and animals. As the program broadened, researchers began to investigate the metabolism of pesticides, when administered to experimental animals both singly and in combination with other pollutants and drugs. Now the effects of pesticides on game birds and other wildlife are being given special attention.

Incidents in Sweden and Japan, as well as in Canada, Montana, and Idaho have emphasized our lack of consideration of the indirect effect of pesticides. Mercury, in particular, seems to have been overlooked. In various forms, mercury is used as a fungicide to prevent mold in lawns and other vegetation, to suppress mildew around commercial laundries, in paper manufacturing, and by the plastics industry. The Swedish and Japanese experiences with mercury poisoning involved primarily fish. Canada, too, has been concerned about mercury-contaminated fish, but in 1969 also recognized a dangerous situation in pheasants and Hungarian partridges.

After Alberta closed its hunting season because of high mercury levels in game birds, Montana officials promptly collected and analyzed specimens of their state's Huns and pheasants for mercury. They found lower residue levels than had been reported in the Canadian birds, but the Montana birds did carry enough mercury to warrant alerting hunters not to be overly enthusiastic about consuming game birds. More recently, Idaho warned its citizens about eating eggs from chickens that might have been fed mercury-treated grains, or grain grown from mercury-treated seed. Two years of research has demonstrated that a fungicidal seed dressing containing an ethyl mercury compound could reduce the egg production of pheasants more than 75 percent. The test birds were maintained on a diet containing only 10 parts per million (ppm) of the active ingredient. The federal government decreed that mercury was not to be used in the United States as a fungicide to treat grains after 1970.

STORAGE ISN'T WHOLE STORY

The reasons for intensified attention to game birds and animals include their lack of surveillance by agencies that enforce tolerance limits on other foodstuffs. For example, when a researcher in Canada checked Lake Erie and Lake St. Clair fish, he found mercury levels ranging from 1.3 to 6 ppm. This is far in excess of Canadian and U.S. standards of 0.5 ppm. The Montana pheasants and Huns were storing about 2.5 to 5 times more pesticide residues than are considered safe for human consumption. A Maryland scientist has reported DDT residues in deer in excess of the legal tolerances established for domestic animals.

In addition to the potential dangers for human beings, indiscriminate use of pesticides threatens the survival of certain bird and mammal species. Personnel of Utah's Bear River Bird Refuge, for example, have voiced concern about reproductive failures in some bird species. Such failures can

Figure 1. Simplified representation of aquatic food chain. The slow release of persistent pesticide residues from the watershed and lake bottom facilitates their entrance into the food chain.
quite often be traced to some of the ubiquitous, cumulative pesticides in the environment and their effects on calcium metabolism.

White-faced ibis nest each year near Bear River Refuge following their annual migration from West Central Mexico. In 1968, there were 5,200 of these birds in the Refuge at nesting time. In 1969, the nesting population had fallen to 1,775 and by 1970, only 900 birds returned to nest. The ibis egg shells averaged .33 mm in thickness prior to the widespread use of DDT that began about 1946. Today the shells are only about .22 mm thick. In susceptible birds, DDT apparently prevents the deposit of calcium in the eggs, leading to disastrously low reproduction and survival rates. Dieldrin also causes a decrease in egg shell thickness in mallard ducks. Recent research indicates that populations of Peregrine falcons, ospreys, bald eagles, brown pelicans, and several other birds are being reduced steadily to the point of possible extinction because of such pesticide effects.

**TOXICITY TO YOUNG PHEASANTS**

The Nevada Department of Fish and Game in 1969 completed a study that tried to define why pheasant populations in Smith and Mason Valleys had declined sharply since 1966. Mowing mortalities of hens in hay fields averaged 53 to 64 percent annually, but few deaths were due to climatic extremes. It was demonstrated, however, that the common practice of spraying for the alfalfa weevil with ethyl and methyl parathion (at the normal application rate) is highly lethal to very young chicks. The killing of 29 percent of 5- to 10-day old chicks in the Nevada valleys could be attributed to spraying in early June each year since 1966.

Spraying for the alfalfa weevil with parathion occurs in Cache Valley and Wasatch Front areas 1 to 3 weeks before the first crop is harvested. This is often close to June 1 or June 10, approximately when most pheasant young hatch. An article in the Logan Herald Journal datelined June 10, 1970, recommended that, because of heavy damage of alfalfa hay by weevils, the hay or stubble be sprayed with one of the following: parathion, malathion, methyl parathion, Sevin (cabaryl), Alfa-tox, Diazinon or Guthion. Young pheasants are killed mainly by breathing or dermal absorption of parathion as the spray settles onto the alfalfa fields, while adults apparently are not adversely affected at this time.

Parathion is an extremely toxic pesticide and exposure to it has caused many cases of human illness, with several deaths having been described. Accidents with this chemical in California have occurred in spite of close regulation and strongly-worded precautionary instructions. A mixture of malathion and methoxychlor pesticides with relatively low toxicity for man, domestic animals, and wildlife could be substituted for parathion in weevil control programs. The health benefits for the farmer and his livestock as well as the resident
wildlife should more than offset any additional cost.

Even in the better pheasant habitats throughout the United States, pheasant populations have been steadily decreasing since DDT and other persistent and even more toxic pesticides began to be used widely and heavily. Recent research studies, however, have pointed out another possible culprit. In one test of pelleted nitrogen fertilizers, which became popular about the same time as DDT, 280 pellets killed pheasants weighing up to 33 ounces. Smaller amounts could induce serious physiological damage and thus affect the bird's reproductive potential. Unfortunately, the birds do not discriminate against the fertilizer pellets when they are feeding.

Nor do the chemicals applied to plants or soils discriminate about where they go from the point of application. For example, the same nitrogen fertilizers that so beautifully boost production of some crops, yet can kill pheasants, have also been implicated in some well-contamination problems. Wells in Northern Illinois, Wisconsin and California have definitely been identified as having nitrite levels sufficient to cause kidney damage and a blood abnormality in children.

In considering unexpected sources of pollutants, it is also of interest to know that arsenic is not only used in some baits. This potent poison occurs to some degree in products of all major soap and detergent manufacturers. Thus arsenic can enter the ecological cycle from a variety of sources.

**RESULTANT REGULATIONS**

Since 1964, the three departments of the U.S. government involved in pesticide regulation have attempted to enforce more stringent controls. This year, the three departments formally joined in a new agreement to institute stronger pesticide laws. The Department of Health Education and Welfare will continue to evaluate pesticide products for their possible effect on human health. The effects of pesticides on water quality, fish, and wildlife, and the general environment are to be evaluated by the Department of the Interior. The Department of Agriculture is responsible for pesticide registration (which are essential if the product is to be marketed).

The U.S. Department of Interior (USDI), which administers approximately 70 percent of all federally owned lands, has banned the use of certain pesticides on its lands or in programs run by its various bureaus and agencies. The 16 banned pesticides include DDT, aldrin, 2,4,5-T, dieldrin, endrin, heptachlor, lindane and toxaphene.

The use of other pesticides is to be severely restricted by USDI personnel. The restricted chemicals are to be used only when non-chemical techniques have been considered and found inadequate, and when use can be limited to small-scale applications. Their use must be aimed at a specific
pest problem, and must involve minimum rate and frequency of application. No pesticide is to be used by the USDI personnel when water quality may be degraded and/or when fish and wildlife, their food chains, or other components of the natural environment may be threatened. The restricted list includes the following pesticides: chlordane, demeton, parathion, picloram, and TEPP.

Various groups of citizens around the country are also trying to generate modifications of past attitudes towards the use of pesticides and toward the environment in general. For example, the Environmental Defense Fund (EDF) is a nationwide coalition of scientists, lawyers, and citizens. They turn primarily to legal action in the courts to try to protect environmental quality. The Colorado Committee for Enviromanental Information confines itself to Colorado and operates on the basis of donated time from concerned individuals. The group effectively gets information to, and the attention of, the state’s politicians and other citizens regarding environmental problems.

As more surveys and research are begun into pesticide residues and effects in birds and animals—more attention must also be given to the complexities of what is being investigated. Species differences, individual differences, differences in the combinations of chemicals to which individuals are exposed, differences in persistence and in cumulative potentials—all of these and still more variables have to be considered. And always, both sides of the scale have to be fairly and objectively assessed.

Is it better to spray a forest to protect it from the ravages of a voracious insect and accept the possible side effects of dead and/or nonreproducing wildlife? Or is it better to “let nature take its course” and perhaps see most of the forest disappear—which would also have drastic results for the resident wildlife?

Other equally difficult questions await answers—what if the use of DDT, but not other pesticides is banned? Are we going to end up better or worse off? What will happen to populations of disease-carrying insects if insecticides are unavailable? Does it really do any good to pass prohibitive laws in the U.S. and other countries while much of the world increases its use of the chemicals in question? And of course there are the economics of food production to keep in perspective.

No one can provide quick, easy, fool-proof answers to such questions. Only continued patient research can give us the necessary insights. But the existing situation can serve as an immediate warning against thoughtless or short-sighted tampering with nature. Man’s power to “manage” the world he inhabits has to be coupled with a vigorous sense of responsibility.
Pesticides and ecology

Ecology has become a much misused term. Because of this, a definition in some detail must be considered before an adequate discussion on the relationship of pesticides to ecosystems can be undertaken. Ecology, as most ecologists accept the term, is defined as the study between organisms and their environment. Since organisms are organized in a functional hierarchical relationship to each other in the environment, ecology can also be defined as the study of the structural and function of nature.

ENERGY SYSTEM

Take, for example, the system of energy from the sun, plants, animals which feed upon the plants, animals which feed upon other animals, and decomposers which feed upon all plants and animals, to illustrate this relationship. Add to that system such factors as temperature, air quality, soil quality and other physical and chemical factors all of which influence, to some extent, the production at any of the above given hierarchal positions and we have very crudely presented an ecosystem which illustrates both structure and function. Such a system is illustrated in figure 1.

Energy in the form of sunlight is utilized by plants for their growth which can be considered as energy storage in the plant biomass. These plants in turn are fed upon by animals, thus affecting a transfer of stored energy from the plants to the animals. The animals in turn are fed upon by other animals, the carnivores, affecting a further transfer of energy up the food chain. In all three levels, natural death occurs which in turn activates the decomposer level which functions to reduce the dead biomass to a more elemental form for circulation through the nutrient pool making it once again available for incorporation into the plant and animal biomass. Thus, we can see that as long as energy from the sun is available this system will continue to function as a machine will function when energy is supplied to it. As with a functioning machine, when energy is converted from one level to another, heat (energy) is lost. Therefore, energy must constantly be put into the system to maintain its operation.

Bear in mind that what is presented here is a very simple system; such simplicity is not likely to occur in nature. For example, each of the hierarchal levels of energy storage such as the plants, the herbivores, or the carnivores, is made up of not one species of organisms but many in any given ecosystem. Each species is represented by a population of the species in either the same or other levels of energy storage. To illustrate this phenomenon take the example of the columbine, which requires the shade of a forest canopy before it can grow. One plant is dependent upon the growth of another plant before it can successfully grow and reproduce. In nature, many hundreds of thousands of examples like this exist.

SOME COMPLEXITIES

Similar situations exist between levels of energy storage. The jackrabbit is dependent upon the production of plant materials for its existence. At the same time the coyote is dependent upon jackrabbit production. In a more complex manner the jackrabbit population, is to an extent, dependent upon the coyote population for its population health. If coyotes were entirely eliminated, jackrabbits could possibly outgrow the range in which they are foraging and thus suffer a crash in their population. These examples serve to illustrate the complexity of ecosystems.
Complexities notwithstanding, it is clear that the organisms of a given ecosystem are inextricably dependent upon each other and upon the environment in which that ecosystem has developed. Any change in any portion of that system will affect the entire system. Therefore, if we take as our example the system illustrated in figure 1 and remove the decomposer level, the available nutrients would soon be used up and the system would either reach a static level or crash. If we remove one of the other levels of production such as the primary producer level, the system would obviously crash.

From this presentation, two important observations concerning pesticide effects on the ecosystem can be made. These include (1) the toxic effect of the pesticide on any portion of the system and (2) the fact that the system by virtue of its moving energy up the hierarchical ladder can concomitantly move pesticides up that ladder. Let us examine the first of these factors.

**SPECTRUM RESPONSES**

Pesticides are toxins. Their primary function is to kill undesired organisms. Unfortunately, the effects of a pesticide are not selective but generally result in broad spectrum responses among wide classes of organisms at greater or lesser levels of concentration. Even if the pesticides used were selective to a single species or organism and that species were an important part of the ecosystem, the effect on the system would be pronounced. However, to make the problem even more complicated, most concentrations of pesticides in the environment are sufficiently low so as not to kill all of a given species. Such sublethal levels may produce effects which may be physiologically debilitating to a species thereby affecting their growth, reproduction or movement capabilities. Hence, the result is a long term effect rather than an immediate effect. Examination of figure 2 reveals the general mechanism by which species respond to levels of a toxicant. Virtually all species, plant and animal, will respond to a distribution of concentrations of a toxicant or to a given concentration over time in the same manner. The response measured can be mortality, growth, or other expressions of physiological activity.

For the sake of this discussion let us address ourselves simply to the mortality response. Note that as the concentrations increase the response in mortality of a species increases to a maximum of total mortality of that population. Thus if the concentration were low, only a portion of the population would die. Those surviving presumably would have some degree of resistance to the toxicant. This manner of response to toxicants provides the basis for natural selection eventually producing a population that might be resistant to a given toxicant. This has happened with the mosquito and DDT.

**PESTICIDE SPREAD**

Realistically, pesticides upon application become part of the environment. Many pesticides, particularly the halogenated hydrocarbons are extremely longlived in the environment. They do not readily break down into nontoxic elements. If we look at the effect of a toxicant on a population in the environment we must consider the exposure of a population to a given level of a toxicant over a time interval as well as exposure to a range of concentrations over a short period of time. For an example of the latter case, a large amount of DDT coming down a stream would subject plant and animal populations in that stream to exposures of a spectrum of concentrations.

Depending upon the pesticide level and exposure time, a given pesticide will influence a given population or several populations in an ecosystem. The sum total of these influences will have an effect on the functioning of the entire system. If that effect is on significant elements in the system, the entire system will crash or be significantly altered. To predict the result on the system of any given pesticide use is difficult to say the least, although not impossible. Currently ecologists are extending the capability of systems science to ecosystems and are striving to produce valid predictive models. Once these models are implemented and functioning, the effect of pesticide on a given ecosystem can be predicted, and no doubt this procedure will be utilized to assure much wiser use of pesticides.

The second important aspect of the ecosystem is the manner in which energy flows through it. The halogenated hydrocarbons are very persistent in the environment. In addition, they tend to be lipophilic, that is attracted to and retained by fat within the body. If, for example, DDT is emitted into an environment it can be incorporated quite easily into the biomass of plants such as the diatoms, which have high oil concentrations. The DDT, being lipophilic, is concentrated in the oils of the diatoms. Now the diatoms are fed upon by invertebrate organisms that also have fat as body constituents. Fish feed upon the invertebrates and the DDT is carried on to them. Although organisms ascending the evolutionary scale tend to detoxify DDT as it is ingested, a good portion of it persists in the body fat. As the DDT is transferred up the food chain it is further concentrated.

**PESTICIDE CONCENTRATION**

Now, in this simple system just expressed—diatoms to invertebrates to fish—consider the energy cost of converting diatoms to invertebrates and converting invertebrates to fish. As indicated earlier, an energy tax is paid for this conversion. In other words, heat is lost by the burning of biochemical material passed up the food chain. That means, in a very general sense, that for every 100 pounds of algae ingested by invertebrates only 10 pounds of invertebrates are produced and for every 10 pounds of invertebrates ingested by the fish, only 1 pound of fish is produced. If the concentration of DDT remained level or was little affected by the detoxification process, then obviously that
which was incorporated into 100 pounds of algae is now concentrated into 1 pound of fish, often bringing the level of concentration in the fish up to levels unacceptable for human consumption. This is exactly what happened with the coho salmon populations in Lake Michigan. There, the algae are consumed by invertebrates which are ingested by a small forage fish called the alewife which in turn are prey to the coho, making a four-step food chain and an additional concentration factor. From this phenomenon it is quite possible to have relatively low levels of pesticide in the environment, but as they are concentrated by the hierarchal chain in the ecosystem they soon achieve levels which can be lethal. If we refer again to the coho salmon in Lake Michigan, we find that the coho has had difficulty in reproducing. To a large extent this difficulty in reproduction is an expression of the phenomenon just explained. The DDT is concentrated in the body fat and passed on to the eggs of the female and incorporated into the yolk of the egg. As the embryo develops, it consumes the yolk which eventually releases the DDT which in turn kills the embryo.

Up to this point we have talked of the simple effects of a single pesticide on a population or populations within an ecosystem. Realistically, as pesticides are utilized by our society, we find that many different forms of pesticides all with differing degrees of toxicity and endurance in the environment, are used. Organisms are very often subjected not to a single pesticide but to a spectrum of pesticides. To complicate the above process we find that pesticides tend to interact in their effect within organisms. For example, fish that have been subjected to dieldrin and subsequently subjected to DDT, show a reduced response to DDT. Other examples can be given where two or more pesticides acting together can produce a response greater than the same concentrations of any single pesticide.

In summary, pesticides in an ecosystem produce very complex effects on that system; effects which are difficult to predict. However, with the continuing progress in the science of ecosystems analysis we should shortly bring the state of the art to the point where we will be able to predict what happens to an ecosystem when subjected to pesticides and thereby be in a much better position to manage and control their use.

THE UNIVERSITY'S ROLL IN POLLUTION CONTROL

Man's manipulation and disruption of his shared environment has recently resulted in a progressive decrease in the overall "quality of life." A major factor in this accelerating decrease of environmental quality is the use of man-made chemicals in the environment. These chemicals enter the environment intentionally (through direct use, their wastes, and their by-products) and unintentionally through accidents and residues. In addition, industrial pollution and pollution by the internal combustion engine have contributed to the environmental load of pollutants.

Our total environment may be divided into three subenvironments and monitored separately. The internal environment is that of the tissues, fluids, organs, and skeletons of the body of man and of his useful plants and animals. The immediate environment is that which we eat, drink, breathe, and contact daily. The general environment consists of the soil, land, air, and water. A change in the general environment is likely to be followed

(Continued on page 44)

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A brief history of pesticide use

REED S. ROBERTS

There are many things that we know about the history of life upon this planet earth and the development of civilizations, but it often takes some unique event to give us a real insight into the full significance of what has happened. This new awareness fires our imagination and as we ponder what is going on, we gain new perspectives. Two recent events have substantially changed our way of thinking. Rachael Carson's book, "Silent Spring" created a sense of urgency and concern on the part of many people and caused even those who didn't agree with her to take a new look at what we were doing with regards to pesticide usage.

Then, when the first pictures of our earth from outer space appeared on T.V., we suddenly became much more aware of the fact that this tiny biosphere is the only place in the universe where life exists as far as we knew. We then realized, more than we ever had in the past, that such problems as pollution, overpopulation, and starvation were very real and very near. Survival even seemed at stake.

Maybe, as part of this new awareness of man's place in the universe, we need to understand the long and painful struggle that has taken place since the beginning of time to determine who would inherit the earth. Man is the only one of millions of organisms which struggles for survival on this earth. His relationship with other living things ranges from mutualism to direct competition. It is with this latter that we are most often concerned. Historically speaking, the insect pests have been worthy competitors.

EARLY USES

We can best appreciate this struggle between man and his insect competitors by briefly checking back in history. Nearly 3,000 years ago, Homer, the epic poet and author of the Iliad and the Odyssey, mentioned pest averted sulfur with its properties of divine and purifying fumigation.

An Egyptian writer in the time of Rameses II (1400 B.C.) showed compassion for the peasant by writing, "Worms have destroyed half the wheat, and the hippopotami have eaten the rest; there are swarms of rats in the fields, and the grasshoppers alight there."

There are many references in ancient literature and in the Bible, which refer to the swarms of insects which devoured everything in their way. Even before the time of Christ, the Romans applied hellbore in an effort to control rats, mice and insects.

By 900 A.D., the Chinese were using arsenic to control garden insects. Before 1300, Marco Polo wrote of mineral oil being employed against the mange of camels.

Arsenic was used with honey as an ant bait by 1669, and by 1690 tobacco was employed as a contact insecticide.

In 1746, Collison in England, recommended to Bertran in America the use of an infusion of tobacco leaves as an insecticide for the control of the plum curculio.

As early as 1763, ground tobacco was used in France to kill aphids.

By 1773, nicotine fumigation was employed by heating tobacco and blowing smoke on infested plants, and in 1787 soap was mentioned as an insecticide and turpentine emulsion was recommended to repel and kill insects.

The use of tobacco against soft-bodied insects was well established before the discovery, by Posselt and Reimann in 1828, that nicotine was the active alkaloidal principle of tobacco.

Not until nearly 1900, however, did commercial nicotine extracts appear on the market. A concentrated extract containing 40 percent nicotine in the form of sulfate was patented in 1908, and in 1917 dusts made with nicotine sulfate impregnated in lime or clay were developed.

1800 TO 1900

Dozens of chemical compounds were tried and used for insect control between 1800 and 1900. The list is long. The following are mentioned because some of them are still used today.

Bordeaux mixture
Carbon disulfide
Creosote
Cryolite
Derris
Fluorine compounds
Hydrocyanic gas
Kerosene
Lead arsenate
Lime sulfur
Naphthalene cones
Nitrophenol compounds
Oil of citronella
Paris green
Petroleum
Phenols and cresols
Pyrethrum
Rotenone
Sodium arsenite
Turpentine

"Pyrethrum", made from a daisy-like African flower, is perhaps the oldest of the organic insecticides; the date of its first use is unknown. It has been claimed that Marco Polo brought pyrethrum to Europe from the far east.

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as a wondrous compound of secret origin. Pyrethrum powder was introduced into the United States from Europe before 1860. By 1890, entomologists were recommending kerosene extracts of pyrethrum to be applied as soap emulsions for the control of plant infesting insects. By 1928, it was being processed and sold in large quantities.

Next to rotenone, pyrethrum is the most commonly used botanical insecticide in Utah. It is primarily used as an insecticide to control household pests.

Since 1949, a synthetic pyrethroid, allethrin, has been made commercially on a large scale.

“Rotenone”. Primitive people have long used poisonous plants containing toxic substances to kill fish. One of these substances from tuba root was recommended in 1848 for controlling insects attacking nutmeg trees in Singapore. Later, the active principles in these fish poisons were named rotenone, and by 1920 rotenone was recognized as an insecticide. Its principle use has been to control specific insect pests of crops such as the Mexican bean beetle and pests of livestock such as cattle grubs.

Rotenone is reported to be the most commonly used botanical insecticide in Utah.

“Paris green”. Many compounds were developed as a means of combating a specific insect pest. An interesting example of this concerns the Colorado potato beetle, Leptinotarsa decemlineata Say. This voracious insect was a native of the Rocky Mountains where it fed upon native solanaceous plants. As agriculture pushed westward and introduced the potato, the insect rapidly moved eastward where it caused considerable damage.

It is not known who originated the idea of using Paris green against the potato beetle, but it was first used in the West in about 1865. Since satisfactory sprayers were not available at that time, the poison was put on the plants with brooms. Its usefulness in controlling the Colorado Potato beetle was soon recognized and it was then used to control other insect pests.

1900 TO 1935

The first third of the twentieth century saw the introduction of several new insecticides, including the following:

- carbon disulfide
- chloropicrin
- calcium arsenate
- ethylene dichloride
- methyl bromide
- paradichlorobenzene
- pentachlorophenol

Just prior to World War II, several dinitro and thiocyanate compounds were developed.

The 1940s saw the introduction of the chlorinated hydrocarbons and organo-phosphorous compounds.

“Methoxychlor” was first made in 1893, but it wasn’t really discovered as a valuable insecticide until 1940, by Dr. Paul Muller of the Geigy Company in Switzerland.

Methoxychlor is said to be more effective than DDT against some insects and has a distinctly lower toxicity to vertebrates. It is said to give a more rapid knockdown of many insects than does DDT.

Recently, about 75 percent of the methoxychlor sold is used for fly control on cattle and in farm buildings, with the remainder divided between crops, control of elm bark beetles (Dutch elm disease), grain bin treatment, home garden and household insecticides. The largest recent shift has been in crop use; from primarily fruits and vegetables in earlier years, to forage crops particularly alfalfa weevil control.

“DDT”. The history of DDT is a story in and of itself. It was first described in 1874 by the German chemist Othmar Zeidler, but its insecticidal value was not discovered until 1939 by Dr. Paul Muller of the Geigy Company in Switzerland. It was used in the field, mostly by the military in the early 1940s.

It was patented in 1942 and introduced in the U.S. that same year. It soon became the best-known, most economical and most astonishingly effective of the synthetic insecticides.

Most DDT usage is now limited to malaria control and related programs in developing nations.

“BHC”. Benzene hexachloride was first made by Michael Faraday in 1825, but it wasn’t until 1933 that Harry Bender, an American chemist, mentioned that the benzene hexachlorides appeared to be good insecticides. By 1943, it was discovered independently both in England and France that benzene hexachloride was highly insecticidal. It was soon used to replace derris in flea beetle control. Actually, this well known chemical should be called HCH, hexachlorocyclohexane, but the other name still persists.

Shortly after the discovery in 1943 that BHC was an effective insecticide, it was found that the gamma isomer was the most active of the isomers and it was called lindane.

“Toxaphene” was first tested against insects about 1945. It has proved especially useful in the control of grasshoppers, cotton insects and pests of livestock. It is reported to be the most commonly used chlorinated hydrocarbon insecticide in Utah.

THE CYCLODIENES

The cycloienes, such as aldrin, chlordane, dieldrin and heptachlor, are related to DDT in the sense that they are chlorinated hydrocarbons. They are all cyclic, but in spite of their generic name, only a few are dienes.

Many of these compounds were developed in and after 1945 by Julius Hyman in the United States. Following is a brief discussion of some of these.

“Chlordane”. This cycloidiene was
developed in Germany by Riemschneider in 1945. It has since become one of our most useful insecticides. The agricultural usage of chlordane is primarily as a soil insecticide, however, it has been particularly effective against grasshoppers, ants, and cockroaches. It is also useful in structural pest control.

"Dieldrin". This has been and remains one of our most effective insecticides. It is especially valuable as a soil insecticide being used to control many different kinds of root infesting insects and termites.

"Thiodan (endosulfan)". This compound was introduced in 1956 in Germany. It is registered in the United States for use on over 75 different plants for the control of dozens of insect pests.

"Aldrin" was commercially produced in 1950. It has been effective and extensively used soil insecticide. Roughly one-half of the U.S. corn acreage treated with soil insecticide in the past has been treated with aldrin. Particular insects of economic importance that were controlled are ants, cutworms, wireworms, flea beetles, Japanese beetle grubs, seed corn beetles, seed corn maggots, European chafer grubs, white grubs, corn bill bugs, sugarcane beetles, webworms, white fringe beetle grubs, crickets, and corn rootworm larvae.

"Endrin". The major domestic use for endrin is as a cotton insecticide. Substitute insecticides are being evaluated in India. These studies indicate, however, that substitute insecticides for control of rice and cotton insects would increase the cost of treatment 80 to 95 percent.

THE ORGANOPHOSPHATES

The discovery that the organophosphates were insecticidal was made by the Germans during World War II. A number of these compounds were known as nerve gases. It is to Gerhard Schrader in Germany that we owe the discovery of their suitability in agriculture, initially as a substitute for nicotine.

The first of these products was bladan, which was soon followed by tepp, parathion and methyl parathion.

Parathion was discovered by Schrader and has become one of the most widely used of all the organophosphorous insecticides. It was made available in the U.S. in about 1946. It is effective against a wide range of insects and mites.

Methyl parathion was introduced in 1950 and malathion in 1952.

There are at least 30 commonly used organophosphorous insecticides now widely used to control over 200 different insect pests. Space prohibits a listing of each, but if one disregards the negative aspects of the matter, we literally have an organophosphorous compound to control every insect pest.

OTHER INSECTICIDES

"The Carbamates". Although substances containing carbamic acid were known to be poisonous before 1864, it wasn’t until 1947 that the Geigy Company of Switzerland began work which led to the first insecticidal carbamates. These were the N-dimethyl carbamates.

It was almost 10 years later, that the best known of the present carbamate insecticides, carbaryl (Sevin R) was described. Now there are several carbamate insecticides available, two of the more common ones being methomyl (Lannate R) and zectran. Carbalry is probably the most commonly used carbamate insecticide in Utah.

"Aerogels". Man has often tried such inert compounds as ashes, road dust and soot to control insects, however, in 1959 it was observed that dusts would control termites and that the silica aerogels were particularly effective in this regard.

Since then silica aerogels in combination with insecticides, such as the pyrethrins, have been used to control termites and cockroaches.

(Continued from page 41)

POLLUTION CONTROL

(Continued on page 46)
PESTICIDES IN PUBLIC HEALTH

PREPARED BY LYMAN J. OLSEN, M.D.

One of the major hazards of problem solving is the possibility that in solving one problem we create another as bad or worse than the one we try to correct. Physicians have found this to be so in many areas when they have suddenly found the cure to be worse than the disease.

This situation is becoming a fact of life as we try to solve problems in air and water pollution and find, to our regret, that we have created other difficulties in their place.

The problems of providing sufficient high quality food for a burgeoning population and the need to control diseases that ravage entire continents has led to such a new monster—the "Pesticide Problem" in today's world.

Pesticides have been with us for many years and in many different forms. There is no question that they have contributed greatly to our way of life. Diseases of historic importance have been brought under control. Malaria, typhus, cholera and others have fallen before the onslaught of pesticides. Increased health and economic gains have resulted from their use throughout the world. Better food and products have become available in the wake of their use. That use, however, is a sword that cuts two ways.

Pesticides were first used for public health in 1892 when L. O. Howard discovered that kerosene was effective in killing mosquito larvae. Shortly after this, Cresylic acid, Paris green and Pyrethrum were found to be useful and Paris green is still found useful in some circumstances.

Pesticide production, which reached several million pounds per year in 1900, has continued to grow, especially after World War II. The most recent reports show production of over 60,000 formulas, using up to 600 chemicals in pesticide production with hundreds of new formulations being proposed each year. In addition to pesticides, the production of herbicides has also skyrocketed, to add to the burden of our environment.

PESTICIDES AND ENVIRONMENT

Pesticides then become part of our total environment. Our air, water, food, and the soil become contaminated with these materials and become either a direct or indirect threat to our lives. The most serious problem is perhaps the biological magnification that takes place in the food chain as the pesticide advances from soil and water to the food we eat. These substances, then, reach us through air, water, skin and food and gain access through contact, oral, and respiratory routes to contribute to our body burden.

What are the alternatives to the pesticides? There are several methods, but they are less easily used on a mass scale. Proper drainage of breeding grounds of mosquitoes and elimination of refuse which contributes to breeding rats and other vectors of disease. One biological control uses sterile males to ensure that fertilization does not take place, thus breaking the life cycle of the pest in question. Another method, one with some danger, is the use of natural enemies of the pests such as fungus or other organisms. The danger here is that a natural enemy to one pest may become a hazard itself if not carefully used.

LYMAN J. OLSEN, M.D. is the State Director of Health.

MAJOR PROBLEMS

A major problem in the use of any pesticide is the decontamination and disposal of the equipment and containers so that they in turn do not become a public health hazard. Along with the disposal, safe storage is also a problem. It has not been too long ago that several deaths took place in South America because a pesticide was mistaken for flour and used in baking bread. Numerous errors of this type have taken place because of improper handling. At least one death has occurred because a child sucked the fluid off a nozzle that had just been used in a spraying operation.

Pesticides should be stored separately in an area that is cool, dry, and well ventilated. Access should be limited, and areas kept locked. Every container should always be appropriately labeled. Pesticides should never be kept in pop bottles or food containers. Any large storage facility should be made known to fire protection personnel. Toxic smoke, explosions or contaminated water could result from combating such a fire. Different pesticides should be kept from each other to prevent contamination or possibly explosions. Protective equipment and emergency procedures should be available and known to all handlers of the material.

In disposing of the containers, flammable material should be burned in an isolated area. Containers should not be reused. Herbicide containers should not be burned since they may not only explode, but the volatile fumes can damage nearby plants. Containers may be buried, decontaminated with other chemicals or large ones recycled. In any event, they should be prevented from contaminat-
TREATMENT

Treatment for poisoning by pesticides will vary according to the agent used. In every situation, however, emergency measures should be made known to users and workers in storage areas. Poisonings may be acute or chronic, and symptoms will vary. All workers should be aware of symptoms of chronic as well as acute effects. These are too diverse to discuss here. Briefly, however, some suggestions might be given:

1. If breathing is difficult or has stopped, clean off any residue, and give mouth to mouth resuscitation through material such as a clean handkerchief.
2. Notify a physician immediately.
3. Take label of container.
4. If inhalant poisoning, move to fresh air—use appropriate respiratory equipment before entering a closed area.
5. Remove contaminated clothing and wash immediately.
6. Induce vomiting if no corrosive involved and patient is conscious.

The National Clearing House for Poison Control Centers in 1966 reported 4,438 ingestions of pesticides, or 7.1 percent of all reports. The true number of ingestions would be hard to determine, since many are not turned into poison control centers. The majority of cases occurred during the spring and summer months (66%) as expected. More than 87 percent of poisoning occurred in children under 5 years of age. Seventy-five percent of these ingestions were insecticides and rodenticides.

Chronic exposure to pesticides may have effects unrelated to acute poisoning. We know far too little about the possible synergistic effects of pesticides with other chemicals or within the body. We know virtually nothing about carcinogenic potential, mutagenicity, and teratogenicity, or the effects on behavior or mental functioning. Many have not been tested at all for these effects, and animal tests are not directly applicable to the human.

REGULATIONS

State and federal regulations have been strengthened in recent years. The Utah Legislature in the 39th Session in 1971 enacted a new Control Act for pesticides that tightens up the usage and purchase of these agents. An Advisory Committee also has been created to decide which if any pesticides may be used or banned. The Federal Drug Administration has a program as follows:

1. Establishment of tolerances or limits on the amount of pesticides on food.
2. Surveillance to find out whether residues are within tolerances.
3. Information and education activities.
4. Control activities to remove over tolerance foods from the market.

POLLUTION CONTROL

(resources that the pollutant may affect.

These goals cannot be accomplished without a sufficient number of trained technicians, technologists, engineers, economists, administrators and scientists, and without the requisite scientific, technical, and economic knowledge.

Our universities obviously have the responsibility to train scientists, economists, and engineers who are able to produce the knowledge and technology that will result in restoration and maintenance of a clean and healthy environment. Two programs have to be established: (1) departments specifically oriented towards environmental toxicology and related problems; and (2) federal aid to fund the research of the university. The establishment of departments of environmental toxicology containing scientists of many disciplines allows a department two distinct advantages. First, is the ability to attack a problem from several sides instead of just one. Second, as a task force oriented department, research funds may be more economically employed and the ability of the department to acquire the necessary funds for such programs may be enhanced. Several top universities such as the University of California, Pennsylvania State University, and Massachusetts Institute of Technology have already demonstrated this approach.

Federally oriented programs and agencies are many times confounded with inefficiencies that inhibit their ability to effectively deal with a problem. The university and private agencies are generally less inhibited by inefficiencies. (Continued on page 49)
CHLORINATED HYDROCARBONS
CAUSE THIN EGG SHELLS
BUT SO MAY OTHER POLLUTANTS

R. K. TUCKER

There has been no 'Silent Spring' yet. But there are examples of whole bird populations such as the peregrine falcon, osprey, or pelican which have crashed. For some birds, such as the Anacapa Island pelicans, a 'Silent Spring' is developing.

As a researcher, I want all the facts and experimental evidence I can garner before coming to a conclusion. But as a member of the human community, I wonder if it will be too late for wildlife by the time we completely understand what DDT or other pollutants can do and how they do it. It may be that we must decide before all the facts are in.

In the Denver Wildlife Research Center's work with pesticide-wildlife relationships, it became obvious that while the problems are ecological in nature, the solution to all the problems could not be found solely through field research.

Hence, the Research Center has tried to develop a balanced program including field research and also laboratory studies. Field studies by wildlife biologists identify a problem, chemists determine pesticide residues present, and we in physiology and pharmacology research the meaning and effects of the contamination. The first information we seek is the acute toxicity of the pesticide including dose-response curves, LD50S, symptoms of intoxication, and gross pathological changes. We use several representative species with several routes of administration and carefully review these studies of comparative toxicity. Next, short term repeated exposures and chronic exposures are run. After the toxicity phases are completed, reproduction studies take place. In all of these, we try to relate "laboratory or pharmacological susceptibility" to "field or ecological vulnerability."

With this background, let's examine further the effects of pesticides on avian ecology from the standpoint of research at the Denver Wildlife Research Center.

One possible effect of pesticides on birds is the production of thin egg shells. Of 300 eggs laid last year by Anacapa Island brown pelicans, nearly all were thin shelled, many were collapsed, and just five young were successfully produced. DDE residues of 6 to 1800 parts per million (ppm) were found in these birds in the fat and lipid fraction of their tissues. However, in Baja, California white pelicans contained up to 1800 ppm DDE in their tissues and did not lay thin shell eggs. Laboratory attempts to achieve the 50 percent thinning observed on Anacapa have failed. This could be explained in several ways:

(1) in the field where shells are thinner than normal by 20 percent or less, DDE itself could be the culprit;
(2) when thinning exceeds 20 percent, one might expect that other chemicals or a co-action of DDE with other chemicals exists;
(3) or perhaps, in most cases where thinning exceeds 20 percent, extensive egg eating by parents, or cracking and destruction of the shells occurred with high frequency and so did away with the field evidence of thinning greater than 20 percent;
(4) or it may be a matter of species differences.

The species in which egg shell thinning has occurred are among those receiving the highest exposure to DDT. Direct correlations of DDE (a DDT metabolite) residues in bird tissues with the degree of egg shell thinning have been repeatedly made on a colony to colony basis but these correlations have not always held up on a bird to bird basis. Thus DDT or DDE may be an indicator of man's pollution of the nesting area and some other material or pollutant may be present also but distributed differently than DDT within the colony.

Until recently, workers have been handicapped by an inability to duplicate in the laboratory the degree of shell thinning in the wild. Documented cases of 50 percent thinning have occurred in wild birds, but most shells from both laboratory and field collections have 16 to 20 percent thinning. Most laboratory studies have produced only 10 to 20 percent thinning with moderate to high dietary levels of chlorinated organic pesticides. We have now produced up to 28 percent shell thinning in mallard eggs by one large, oral dose of DDT. Thus, it is more plausible that DDT or similar compounds could cause drastic egg shell thinning in the field or in combination with other pollutants.

In 1970, we fed mallards a 40-ppm DDE diet for 79 days on a 8-hours light and 16-hours dark cycle to avoid egg laying while a heavy DDE residue accumulated in their fat. Five to 7 days after switching to 16 hours of light, the mallards laid eggs with shells

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16 to 17 percent thinner than normal. For 42 days after the cessation of the DDE diet, the birds still laid shells 16 to 17 percent thinner than the controls.

We next fasted a new group of mallards for 4 days and then fed them 10 and 40 ppm DDE for 7 days. At the end of 7 days, the birds laid eggs with shells 6.1 to 16 percent thinner than normal, respectively. Only 8 and 37 mg DDE had been ingested per hen in this short time.

These experiments illustrated that only a short term exposure to very small amounts of DDE is required for gross shell thinning. Such thinning can also persist long after DDE exposure is discontinued.

A representative group of common pesticides was administered orally in single doses to laying coturnix quail. Several dissimilar chemicals could cause significant egg shell thinning (table 1). These included tetraethyl lead, parathion, a mercury-containing pesticide (Ceresan M), 2,4-D, and carbaryl. Table 1 shows the average percent of thinning over 7 days. Each of the compounds that caused significant thinning produced 20 percent more thinning for 2 days after the dosing. Such thinning is sufficient to produce cracked and broken shells, but it does not last as long as among wild avian populations.

Just as we were about to conclude that chlorinated organics and particularly DDT were the culprit, we found evidence that many other diverse pesticidal compounds also can produce shell thinning. Interesting? You bet! Let me tell you that technical DDT, op-DDT, DDE, and dieldrin failed to produce egg shell thinning in experiments with the quail. In addition, we’ve found that coturnix quail withheld from water for 36 hours will lay eggs averaging 29.6 percent thinner when drinking is resumed.

We repeated the “coturnix quail experiment” with mallard ducks (table 2). This time dieldrin, DDT, DDE, and PCBs (polychlorinated biphenyls) produced egg shell thinning but the other compounds tested did not. We achieved 16.9 percent shell thinning in mallards by alternately feeding and starving mallard ducks with a 40 ppm DDE diet over 1 week. Comparisons with the controls lead us to believe that the full effects of the DDT family will not be seen fully among steadily feeding birds. Wild, flesh-eating, birds eat only periodically and some of these have shown dramatic egg shell thinning. When mobilized from storage in lipid reserves, DDT may produce the egg shell thinning observed in the field. We have such controlled feeding-lipid-DDT balance studies underway.

We also have studies underway to determine the mechanism of the shell thinning. Possible mechanisms include liver microsomal enzyme induction followed by destruction of vitamin D or estrogen, carbonic anhydrase inhibition, diuresis, DDT acting as a thyroid hormone mimic, and premature egg laying.

We have found that coturnix quail fed 100 ppm of DDT or DDE in the diet for 3 months had 16 to 19 percent less carbonic anhydrase in the shell glands. Blood carbonic anhydrase levels were 22 and 44 percent lower for DDT and DDE respectively. Carbonic anhydrase inhibition could limit the amount of carbonate ions available to form the calcium carbonate that makes up about 95 percent of a shell. According to a recent report, DDT and DDE may not be true inhibitors of carbonic anhydrase, however.

In another experiment, ringdoves given 10 ppm DDT for 8 days showed a decrease of 33 percent in circulating estradiol early in the breeding cycle. There also was a 60 percent decrease in deposition of medullary calcium and there was a 10 to 12 percent decrease in egg shell weight. Hepatic enzyme activity metabolizing estradiol increased 2 to 3 fold.

Thus, the abnormally late breeding seen among certain wild flesh-eating birds may be caused by increased hepatic enzyme activity and decreased estrogen levels early in the breeding cycle. Thin egg shells and consequent breakage and egg eating by the parent birds may be caused by the inhibition of carbonic anhydrase (or another mechanism) and/or the diminished medullary calcium deposits in the endosteal bone areas. These factors can’t explain, however, the increased embryonic mortality, poor survival after hatching, and the reduced clutch sizes that have been observed.

As mentioned above, the egg shell thinning may be caused by a combination of pesticides or industrial pollutants. Therefore, we are conducting studies on interactions of DDE with mercury, lead, and polychlorinated biphenyls.

None-the-less, we have several hypotheses that might explain part of the reproductive failures. These are

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**Table 1. Percent of egg shell thinning in Coturnix quail 7 days after an oral dosage (milligrams per kilogram) of possible pollutants**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dose</th>
<th>Difference, % thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Treatment</td>
<td></td>
<td>+ 1.0</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>10</td>
<td>- 0.3</td>
</tr>
<tr>
<td>Parathion</td>
<td>2.5</td>
<td>- 4.8</td>
</tr>
<tr>
<td>Sevin</td>
<td>1000</td>
<td>- 8.7</td>
</tr>
<tr>
<td>2, 4-D (acid form)</td>
<td>250</td>
<td>- 5.5</td>
</tr>
<tr>
<td>Ceresan M</td>
<td>5000</td>
<td>- 8.6</td>
</tr>
<tr>
<td>Arochor 1254</td>
<td>500</td>
<td>- 4.0</td>
</tr>
<tr>
<td>Tetraethyl lead</td>
<td>6</td>
<td>-14.5</td>
</tr>
<tr>
<td>DDT, ortho para analogue</td>
<td>125</td>
<td>+ 0.5</td>
</tr>
<tr>
<td>DDE, para para analogue</td>
<td>500</td>
<td>0.0</td>
</tr>
<tr>
<td>DDT, technical</td>
<td>500</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Table 2. Percent of egg shell thinning in Mallard ducks 6 days after an oral dosage (milligrams per kilogram) of possible pollutants

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dose</th>
<th>Difference, % thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Treatment</td>
<td>-</td>
<td>-2.3</td>
</tr>
<tr>
<td>DDT, technical</td>
<td>1000</td>
<td>-3.8</td>
</tr>
<tr>
<td>DDE, para para analogue</td>
<td>1000</td>
<td>-16.0</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>160</td>
<td>-3.8</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>1000</td>
<td>-10.1</td>
</tr>
<tr>
<td>Kepone</td>
<td>25</td>
<td>+0.8</td>
</tr>
<tr>
<td>Parathion</td>
<td>1</td>
<td>-26.3</td>
</tr>
<tr>
<td>Sevin</td>
<td>1000</td>
<td>0.0</td>
</tr>
<tr>
<td>2,4-D (acid form)</td>
<td>1500</td>
<td>-0.8</td>
</tr>
<tr>
<td>Ceresan M</td>
<td>500</td>
<td>-21.1</td>
</tr>
<tr>
<td>Aroclor 1254</td>
<td>1000</td>
<td>-4.6</td>
</tr>
<tr>
<td>Tetraethyl lead</td>
<td>6</td>
<td>-1.1</td>
</tr>
<tr>
<td>Sodium arsenite</td>
<td>100</td>
<td>-13.5</td>
</tr>
</tbody>
</table>

being tested further in light of other reports in the literature.

The hypothesis that DDE interferes with utilization of medullary bone calcium may not explain the total thinning. We selected mallards laying shells 16 percent thinner than normal from a DDE-diet group and a group of control birds laying normal shells. We lowered the dietary calcium to 0.8 percent. Those birds that continued to lay eggs would have to draw upon medullary calcium from their bones or lay much thinner shells. The control birds, not exposed to DDE, had more rapidly declining shell thicknesses than the DDE group. Had DDE severely impaired the utilization of medullary calcium, their shells should have suffered most from the dietary calcium deficiency.

Now, I should like to suggest the existence of a large hole in pesticide-wildlife research. The percentage of pesticides upon which avian reproduction studies with American wildlife species have been run is certainly less than 5 percent and maybe less than 1 percent. Of 1,500 petitions for labeling of new pesticides or pesticide uses reviewed by the United States Department of the Interior Pesticide Review staff in a recent 6 month period, only two were accompanied by native American bird reproduction studies.

In addition, the results of our research probably have no impact whatsoever on the public. That small portion of the research findings that do reach the public through the news media is so ridiculously distorted in favor of excitement rather than honesty that it ceases to be research results at all. I'm not aware of a single newspaper article in which a scientist was thoroughly or correctly quoted. The real and rightful impact of our research results should be directed to those employed decision makers who must have the information to make a decision. Of over 6,000 pesticides in use, basic alterations, with one or two exceptions, have not been made by public pressure. Even with DDT, production for domestic use began dropping in 1963 before any public alarm over the egg shell thickness occurred. Projections of the 1963-1966 production figures suggest that DDT may not be used domestically after 1974. For those of you, however, who think DDT is banned today, note that 35 uses are still exempted from any ban. The real reason that DDT will not be used in quantity past 1974 is that insect resistance makes it less and less profitable. In other words, the public has been kicking a dead horse.

We don't always take a negative attitude toward pesticides. If certain pesticides such as DDT are to be eliminated, then safe, suitable substitutes must be found. We, in conjunction with the U.S. Forest Service, believe we've come up with a safe DDT substitute for spruce, budworm control in forests. Zectran, while toxic to birds and mammals, needs only to be applied at 0.13 pound per acre for effective budworm control. It breaks down in 24 to 48 hours in the presence of water and sunlight, has no cumulative toxicity for our test species, and showed no effect in reproduction studies with waterfowl, upland game birds, and deer. Sixteen common organ function tests on blood and urine showed no alterations from normal. Finally, in trial applications on 5,000 acre plots in Montana, our field biologists came to the same conclusion—no effects on wildlife. Zectran is a methyl carbamate insecticide.

Zectran, other carbamates, and the phosphates may replace some chlorinated organic pesticides but that won't eliminate all of our problems. It may even create new ones! Organophosphorus and carbamate insecticidal residues in tissues of wildlife are harder to measure and monitor. Not all organophosphorus insecticides break down rapidly. Azodrin, for example, has been found to persist in stream water with less than 1 percent breakdown in 8 weeks. Organophosphorus and carbamate insecticides are often very toxic to beneficial insects.

The obvious role our physiological and pharmacological studies group will have is to understand the effects of newer pesticides on non-target species of wildlife. But to understand these side effects we need to know how the pesticide will act. In pesticide applications we are often shooting big guns without knowing where the bullet will go or whether a single shot will come out of the muzzle or a maze of shots will cover more than just the intended target. These kinds of problems will be keeping us busy for some time.

POLLUTION CONTROL

(Continued from page 46) efficiency and should be able to function more effectively concerning environmental problems. At the same time however, the federal government should not ignore the problem but should extensively fund environmental research and carry out and enforce the necessary requirements and programs to maintain a quality environment.
Some benefits of pesticides to public health

JAY E. GRAHAM

The benefits of pesticides to public health are great and no pretense is made in this article to cover the subject completely. Hopefully, some perspective can be obtained by considering some of the more important human diseases that are being controlled by the application of various pesticides. For the purpose of this paper, pesticides are defined as those chemical compounds available commercially and widely used to control populations of various arthropods which are the vectors or carriers of human disease.

While the comments here will be limited primarily to chemical control methods and materials, the reader should recognize that all of the adequate control programs use a variety of methods which, lumped together, are called integrated control. In addition, serious and highly sophisticated research programs are underway throughout the world to find alternative methods of control. One of these is discussed briefly later.

THE RISKS

When prescribing a medicine, a doctor weighs the benefits against the risks. In some instances, penicillin for example, the benefits are very great and the risks of side effects are slight but some people do have allergic reactions that are serious. The use of cortisone presents more difficult problems for the doctor since the effects of cortisone on the human body are very detrimental if used for an extended period of time. Sometimes human body disease requires that this risk be taken.

The same principal of weighing benefits against risk applies when applying pesticides. To consider only the benefits or only the risks is a disservice to all of us. Unfortunately, few are qualified to make the proper kinds of evaluations.

In developed, industrialized countries in temperate regions, arthropod-borne diseases are relatively rare today, although some of them have been common and serious in the past. In today's world these diseases present their greatest threat to the peoples of the tropics and semi-tropics who live in cultures where, for better or for worse, modern technology has not developed greatly.

ARTHROPOD BORNE DISEASES

Following is a partial list of the diseases affecting man which are transmitted by arthropod vectors that can be controlled by pesticides: Chagas' disease, epidemic and murine typhus, plague, onchocerciasis, leishmaniasis, tularemia, sleeping sickness, malaria, filariasis, various encephalitides, dengue fever, yellow fever, Colorado tick fever, Rocky Mountain spotted fever, relapsing fever and others.

Of these diseases, malaria has historically been the most important disease of mankind both in numbers of cases and in numbers of deaths. Its debilitating effects on the vigor of civilizations both in the past and at present cannot be overemphasized. Malaria today still divides the rich world from the poor. Malaria was, until World War II, an important disease in the United States, particularly in the southeastern part of the country. In 1934 and 1935, it was estimated that malaria cost the United States $500,000,000 annually.

Today, gauging the impact of malaria on the economy of 1934 and 1935 is difficult. A comparable loss today in terms of the gross national product of 1934 and 1970 would be about 14 billion dollars. This kind of comparison leaves a lot to be desired but it does indicate the seriousness of the disease. Since malaria is many times more serious in other countries than it ever was in the United States, it is no wonder these countries are poor and having difficult problems in trying to develop a decent standard of living.

DDT IMPORTANCE

Malaria was, for all practical purposes, eradicated in the United States during the Second World War. The tool that led to its eradication in the United States was DDT, used as a residual spray in dwellings to interrupt the chain of transmission. This technique became the method of choice for the world wide campaign to eradicate malaria under the auspices of the World Health Organization, and even today DDT is the insecticide of choice for those areas of the world where malaria still exists.

The reduction of malaria in the world has been dramatic but the program has not eradicated malaria. The government of India in its fourth 5-year plan stated that malaria was causing an annual loss of 7.5 billion rupees in 1952. In 1966, this loss was cut to 15 million rupees. Auxiliary benefits that result from malaria control are: mapping, census completion, strengthening of governmental image, skills developed, strengthening

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of governmental relationships, developed health programs, developed international cooperation, technological benefits to control other vector-borne diseases, and control of other insects and diseases.

Major areas of malaria still exist in Africa and part of South America as well as some malarious areas in Asia. The costs of eradication are still too high for some undeveloped nations, and they are now shifting to a control program with the goal to reduce the disease rather than eradicate it. DDT is still the most effective and economical chemical available. If DDT is banned, malaria control will become even more expensive and difficult.

The malaria problem in Africa presents special problems. Residual spraying has frequently been ineffective in controlling the disease and new techniques must be developed. Currently the World Health Organization has a number of research programs in Africa to reach a solution to this problem. One of the promising avenues open to them is to apply pesticides to the larval habitat.

Typhus is another disease of man that responds well to pesticide use. The most dramatic example occurred in Naples, Italy in 1943. An epidemic started there because of conditions resulting from the war. Authorities estimated that 250,000 deaths would result if the epidemic followed the classic course. In December the city population was dusted with DDT powder, and the epidemic was avoided.

DDT also has been used successfully to control other diseases. There is no point in trying to review here all of the public health benefits of this pesticide or to try to review all of the current arguments both pro and con, regarding its use. However, many of the people who are supposedly weighing benefits against detriments are totally unqualified to do so since they remain unaware of the problems of public health on a world wide basis.

OTHER VECTOR CONTROLS

Another spectacular disease of man in the tropics spread by insect vectors and controlled by pesticides is filariasis. The parasite Wuchereria bancrofti that causes the disease persists in the body for several years and can infect biting mosquitoes. This disease in its later stages is popularly known as elephantiasis because of the extreme swelling of the limbs, particularly the legs. Other parts of the body also may be affected. Increasing human populations and urbanizations in the tropics and semi-tropics without a corresponding increase in sanitary facilities have invariably increased the habitat of the vector, a mosquito—Culex pipiens quinquefasciatus. Therefore, the disease is becoming more important. The larval habitat of the vector is water polluted with organic matter. Improper sewage disposal is conducive to producing large numbers of this mosquito and sewage disposal is not keeping pace with population growth.

In its early stages, the disease can be controlled by chemotherapy but only if the population takes the drugs. Since, in its early stage, the disease does not produce severe symptoms and the drug can make the recipient ill, chemotherapy has been less than successful.

A new program is now in progress to interrupt the transmission of this disease by applying a pesticide to the larval habitat of the vector. In the experimental work conducted to date, fenthion has been the larvicide of choice. DDT was rejected for this work because the vector readily develops resistance when exposed to it for extended periods of time. Compounds other than fenthion could be used, one of the most promising being dursban. Dursban was not available when the pilot project began in Burma and there is reluctance to change pesticides in the middle of an experiment, particularly when the insecticide first selected is working well. This program has not been in operation long enough for final analysis of interruption of disease transmission but preliminary results are promising.

Even though pesticides are the method of choice for disease control in many circumstances, the search continues for alternative methods and filariasis control presents one of the outstanding examples of the complexity of this research. The mosquito vector is part of a species complex that has many different populations and subspecies that vary in cross fertility from complete fertility to complete infertility. A number of genetic factors are involved. By using one of these factors, a researcher was able to eliminate a population of this vector in a village near Rangoon, Burma by a method termed cytoplasmic incompatibility. Briefly, he released males of the species which had cytoplasm from a Paris strain of the species. Factors in the cytoplasm were incompatible with Burmese mosquitoes and when foreign males bred with native females, the eggs would not hatch. By releasing 5,000 foreign males daily in a small village, the scientist was able to eliminate the native population in about 3 months.

This technique, along with sterile male techniques developed by the USDA, appear so promising that the World Health Organization has begun a large research project near Delhi, India for the genetic control of Culicin mosquitoes.

Another important disease vector controlled by pesticides is Aedes aegypti, the main vector of yellow fever, dengue fever, and a form of hemorrhagic fever. Yellow fever was the principle reason that the French were unable to build the Panama Canal. Control of the vector with larviciding oils enabled the United States to complete the canal.

The United States has recently completed an unsuccessful attempt to eradicate this species from the South-Eastern United States, using an integrated control program that included pesticides. No case of yellow fever has been reported in this country since 1905, but dengue fever occurs in epidemics with some frequency in Puerto Rico and other areas. These outbreaks sometimes cause the disease to be reported in the U.S. when
tourists are bitten by an infected vector and return home before the disease develops.

This species has been greatly reduced or even eradicated in large areas of South and Central America but in other parts of the world where a suitable climate exists, particularly Africa and Asia, this mosquito flourishes and is an important disease vector. Outbreaks of yellow fever have occurred recently in Africa while outbreaks of dengue and hemorrhagic fever occur with frequency in various parts of Asia and the South Pacific. In many of these areas A. aegypti is a domestic mosquito breeding in various types of water containers around human dwellings, including the containers used for drinking water.

Experimental programs are in progress in several places to control this mosquito by putting a granular formulation of abate in water containers including drinking water. This chemical is practically non-poisonous to man but destroys mosquito larvae at extremely low dosages. Aerial applications of pesticides, usually malathion, over wide areas for adult control have also been successful. This technique would be used to control wide spread epidemics of disease transmitted by this vector.

Bubonic plague, the Black Death of the Middle Ages, is also a vector-borne disease that can, if need be, be controlled by pesticides. Other methods of control keep the disease in check throughout most of the world but periodically outbreaks do occur. In the United States a few cases are reported each year, primarily in Indians of the Southwest who apparently get bitten by fleas from rabbits. Outbreaks have occurred in recent years in Southeast Asia and Indonesia. Insecticides can be used to control the flea vectors or rodenticides could be used to control the fleas' hosts in case of an outbreak. Normal rodent control practices tend to keep this disease in check.

Large areas of Africa are, at present, uninhabitable by man because of African sleeping sickness transmitted by several species of Tsetse flies. Tsetse are common in many areas of Africa but not all are efficient disease vectors. Control methods are varied but various kinds of pesticides, including DDT have been successful.

A number of encephalitides (brain fever) are also transmitted by insect vectors. In the United States the most important arthropod-borne encephalitides are Eastern encephalitis, St. Louis encephalitis, Western equine encephalitis and Venezuelan equine encephalitis (VEE). All of these are transmitted by mosquitoes of various species. Each has a rather complex relationship in nature involving a variety of hosts wherein the virus is non-pathogenic. Man is apparently an accidental host and has not developed a tolerance for these viruses. The treatment for these disease is usually called supportive therapy which means the victim is given as much care as practical but there is no cure. Vaccines are available for horses but not for man.

MOSQUITO CONTROL ONLY ANSWER

Mosquito control is the only practical preventative measure. Control of the vector is much more complex than is generally suspected by the public. Most control programs use a number of control techniques designed to complement each other. The major emphasis, if not major effort, is to eliminate or modify the breeding sources so as to prevent production. In actual practice, the use of pesticides is an important part of most programs. In the United States, with its great wealth, the use of DDT for mosquito control is not routinely necessary and all districts in the country have switched to non-residual compounds. In Utah, the shift to short-lived compounds began in 1955 before any pressure was being exerted to do so. In many parts of the country, mosquito resistance to insecticides has developed to the point that they are no longer effective. In Utah some slight resistance has been detected to dieldrin and heptachlor but these pesticides were eliminated from control programs very early for other reasons.

In the United States the various encephalitides transmitted by mosquitoes are not responsible for a large number of cases of disease. However, when the disease does strike in an outbreak, the results are serious to those who get it. The death rate is relatively high and residual damage, particularly to children, can be great.

Japanese B encephalitis is a serious disease in parts of the Far East. Large numbers of cases occur each year and control is difficult. At present adequate control procedures are not available but research here is progressing. Eventually an integrated control program should develop in which pesticides will play a major role.

PESTICIDES NECESSARY

The foregoing discussion of human diseases carried by arthropod vectors controlled by pesticides has necessarily been generalized and brief. Much had to be omitted. When a serious disease such as malaria is discussed, particularly in terms of overpopulated and under-developed countries, some people feel that the disease should be allowed to run its course as a means of population control. The people proposing this are, of course, not in an area where they themselves will be the victims. However, the way to human happiness and a full life is not through disease, misery, and an early death. In any event, various diseases have not prevented overpopulation and may even have contributed to it. Cultural patterns in Pakistan and India are such that all parents feel they must have children to support them when they are old. Growing old without children is to be avoided at all costs. One way to insure that children survive childhood is to have many children. So we see that man faces many problems and all cannot be solved immediately. Pesticides are now successfully used to reduce some of man's problems which will allow him to devote his time and increased energy to other pressing problems.
The Utah community pesticide study

The types, quantities, and purposes of pesticide usage in Utah were determined for 1969 and 1970. There were 1.1 million pounds of pesticides used in Utah in 1970. This is minimal in comparison with quantities used in adjacent states. There were 61,918 pounds of the chlorinated hydrocarbon pesticides, including 11,348 pounds of DDT used in 1970. There were 182,101 pounds of the rapidly degradable organo-phosphate pesticides used in 1970, and 656,509 pounds of herbicides. Sixty-nine percent of all pesticides are used in agriculture; 18 percent for yards, houses and gardens; 9 percent by commercial applicators; and 4 percent for mosquito control.

Utah is one of 14 states under contract with the United States Environmental Protection Agency to investigate the influence of pesticides on human health. The contract is with the Utah State Division of Health which provides administrative services, and laboratory and office space for the project staff. Sub-contracts have been made with the University of Utah and Utah State University to do portions of the research.

The organization of all the projects is much the same. The program is divided into work units to investigate specific areas of the problem. The Utah project has 10 work units, and following is a brief description of the activities and findings in each of them:

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Stephen L. Warnick was formerly a principle investigator, Community Pesticide Project at the Utah State Division of Health. He is now employed at the Intermountain Laboratories in Salt Lake City.
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<td></td>
<td></td>
<td></td>
<td>128</td>
</tr>
<tr>
<td>Folpet</td>
<td>155</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>155</td>
</tr>
<tr>
<td>Karathane</td>
<td>6,345</td>
<td>91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6,436</td>
</tr>
<tr>
<td>Petroleum oil</td>
<td>86,400</td>
<td>56,550</td>
<td>300</td>
<td>392</td>
<td>12,395</td>
<td></td>
<td></td>
<td>156,037</td>
</tr>
<tr>
<td>Piperonyl butoxide</td>
<td></td>
<td></td>
<td></td>
<td>317</td>
<td></td>
<td></td>
<td></td>
<td>317</td>
</tr>
<tr>
<td>Sulphur</td>
<td>26,500</td>
<td>2,141</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28,641</td>
</tr>
<tr>
<td>Thuricide</td>
<td>2,550</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,550</td>
</tr>
<tr>
<td>Warbax</td>
<td>2,400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,400</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>578,671</td>
<td>67,470</td>
<td>102,610</td>
<td>36,525</td>
<td>165,394</td>
<td>47,051</td>
<td>49,949</td>
<td>1,047,670</td>
</tr>
</tbody>
</table>
1. **Community Profile.** The state was carefully surveyed for pesticide usage. Comprehensive ecological and demographic data, as well as morbidity and mortality data, were obtained.

In Utah, 10,047,670 pounds of pesticides were used in 1969, including 7,593 pounds of DDT (table 1).

2. **Pesticide levels in tissues of the general population.** Each year, 40 fat samples and 400 blood samples representing the population of Utah are analyzed for pesticide residues. Total DDT levels in the adipose tissue of Utah people have decreased from 9.0 ppm in 1968 to 7.0 ppm in 1969 to 5.3 ppm in 1970. Utah levels are slightly lower than the national average. Table 2 is a summary of pesticide levels in Utah people.

3. **Pesticide levels in the environment.** The University of Utah (Center for Environmental Biology) has a sub-contract to investigate environmental pesticide levels. Samples of food, water, air housedust, soil, wildlife, etc. are collected periodically and analyzed for pesticide levels. Pesticide levels are minimal in these samples and would seem to pose no threat to the safety of man or animals.

4. **Investigation of acute poisonings.** Excellent laboratory facilities enable the project to assist in the diagnosis of any suspected human or animal poisonings. In the past year, 24 cases involving humans and 16 cases involving animals were investigated. In only one case was pesticide exposure the probable cause of the problem.

5. **Long-term study of an occupationally exposed population.** Seventy men with heavy occupational exposure to pesticides and a matched group of 30 men not having direct exposure were selected as participants in this study. The men are given a comprehensive physical examination, and three quarterly checkups each year. About 50 clinical and biochemical tests are made of each participant each quarter.

The resulting data are analyzed medically and statistically for differences between the two groups. Differences occasionally show up, but it is yet to be shown that any of these differences are detrimental to health. Tables 3 and 4 are summaries of tests with significant differences between the exposed and control groups in 1969.

6. **Aerial applicator investigations.** One fatal sprayplane crash in 1969, and one fatal and one non-fatal crash in 1970 were investigated to see if the pilot's exposure to pesticides contributed to the crash. In neither case could it be shown that pesticides were responsible.

---

**Table 2. Serum pesticide levels in Utah general population (ppb)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Number</th>
<th>ppDDT</th>
<th>ppDDE</th>
<th>Adipose tissue ppm (total DDT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>72</td>
<td>9.8</td>
<td>19.5</td>
<td>9.0</td>
</tr>
<tr>
<td>1968</td>
<td>237</td>
<td>7.2</td>
<td>15.4</td>
<td>7.2</td>
</tr>
<tr>
<td>1969</td>
<td>267</td>
<td>7.9</td>
<td>20.8</td>
<td>5.3</td>
</tr>
<tr>
<td>1970</td>
<td>439</td>
<td>4.3</td>
<td>18.7</td>
<td>5.3</td>
</tr>
<tr>
<td>Single extraction</td>
<td>172</td>
<td>8.4</td>
<td>15.2</td>
<td></td>
</tr>
<tr>
<td>Triple extraction</td>
<td>843</td>
<td>5.9</td>
<td>19.3</td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>176</td>
<td>3.5</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>377</td>
<td>11.5</td>
<td>24.2</td>
<td></td>
</tr>
<tr>
<td>21 years</td>
<td>104</td>
<td>3.1</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>21 years</td>
<td>911</td>
<td>6.7</td>
<td>19.3</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>1015</td>
<td>6.3</td>
<td>18.6</td>
<td>7.3</td>
</tr>
</tbody>
</table>

**Table 3. Means of tests with significant difference — group as the base variable, Utah (combined 1969 data)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control mean (N=104)</th>
<th>Exposed mean (N=234)</th>
<th>T test sig level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum βHBC</td>
<td>0.9 ppb</td>
<td>2.6 ppb</td>
<td>0.1%</td>
</tr>
<tr>
<td>Serum ppDDT</td>
<td>3.3 ppb</td>
<td>8.5 ppb</td>
<td>0.1%</td>
</tr>
<tr>
<td>Serum ppDDE</td>
<td>19.0 ppb</td>
<td>29.5 ppb</td>
<td>0.1%</td>
</tr>
<tr>
<td>Serum dieldrin</td>
<td>0.8 ppb</td>
<td>3.5 ppb</td>
<td>0.1%</td>
</tr>
<tr>
<td>γ globulin</td>
<td>1.22</td>
<td>1.15</td>
<td>2.0%</td>
</tr>
<tr>
<td>Urine WBC</td>
<td>0.12</td>
<td>0.26</td>
<td>2.0%</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>189.9</td>
<td>198.3</td>
<td>2.0%</td>
</tr>
<tr>
<td>Creatinine phosphokinase</td>
<td>4.46</td>
<td>5.67</td>
<td>5.0%</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>36.86</td>
<td>34.82</td>
<td>5.0%</td>
</tr>
<tr>
<td>RBC cholinesterase</td>
<td>11.33</td>
<td>10.91</td>
<td>5.0%</td>
</tr>
<tr>
<td>Diastolic BP</td>
<td>83.1</td>
<td>88.5</td>
<td>5.0%</td>
</tr>
<tr>
<td>Plasma cholinesterase</td>
<td>4.3</td>
<td>4.1</td>
<td>10.0%</td>
</tr>
</tbody>
</table>

**Table 4. Means of tests with significant difference — serum DDE level as the base variable**

<table>
<thead>
<tr>
<th>Test</th>
<th>I 15 ppb DDE</th>
<th>II 15-20 ppb DDE</th>
<th>III 20-30 ppb DDE</th>
<th>IV 30 ppb DDE</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppDDT (ppb)</td>
<td>2.5</td>
<td>3.5</td>
<td>6.2</td>
<td>10.4</td>
<td>0.05%</td>
</tr>
<tr>
<td>Exp. group (%)</td>
<td>50.9</td>
<td>78.3</td>
<td>75.8</td>
<td>0.5%</td>
<td></td>
</tr>
<tr>
<td>LDH</td>
<td>329.6</td>
<td>332.5</td>
<td>347.2</td>
<td>375.0</td>
<td>5.0%</td>
</tr>
<tr>
<td>SGPT</td>
<td>25.6</td>
<td>22.3</td>
<td>25.9</td>
<td>30.7</td>
<td>5.0%</td>
</tr>
<tr>
<td>Dieldrin (ppb)</td>
<td>2.9</td>
<td>3.5</td>
<td>6.3</td>
<td>6.6</td>
<td>10.0%</td>
</tr>
</tbody>
</table>
7. Special investigations. This work unit has been implemented to investigate areas of special interest. Studies completed or on-going include:

a) The effect of pesticide exposure on some of the enzyme systems of the body.

b) The relationship of pesticide exposure to recovery from anesthesia.

c) The relationship of pesticide exposure to sputum cytology.

d) Biochemical effects in rats produced by DDT dosage.

e) Effects of DDT on calcium metabolism.

f) Pesticide levels in human milk.

8. Chromosome morphology. Blood from 20 of the participants most exposed to pesticides has been subjected to chromosome analysis. Preliminary results indicate a slightly higher incidence of abnormalities than a comparative control group. Additional work will be done in this area.

9. The effects of pesticides on mammals. Utah State University (Department of Animal Science) has been given a sub-contract to investigate the effects of diet drugs and other pesticides on the toxicity, storage, and metabolism of pesticides in mammals. Dr. Joseph C. Street is directing this work and any effects he identifies in his animal studies can be looked for in the human studies.

10. Data management. The results of all the tests, interviews, and examinations are subjected to thorough computer analysis and studied by the project staff for significant findings. The data from all 14 projects are being pooled, making the study population large enough for significance.

SUMMARY

There are hazards connected with the use of pesticides, but the hazards we presently recognize are mostly related to improper use and handling of the chemicals. It would seem wise to address our efforts toward proper use of pesticides, rather than prohibition. Prohibition should be reserved for chemicals proven unusually dangerous.

We must continue to make objective studies, detect offending chemicals or degradation products, and detect dangerous use patterns.

Research, such as the community pesticide studies are doing with workers heavily to pesticides, is the best means of protecting the public from any harmful effects caused by these chemicals.

Man derives much more benefit than trauma from the use of pesticides. For the present, it appears that the sensible use of these chemicals is an essential weapon to use in man's battle with insects for survival.

What can USU do about pesticides?

Utah State University with its broad involvement with people, the environment, and agriculture has a major responsibility in the area of pesticides. We are doing basic research with them. We are testing and demonstrating their use on crops, livestock and humans. Life would be very miserable to us if we did not control undesirable insects. Crop and livestock production would be seriously hampered without effective means of controlling insects, weeds and plant diseases.

In some ways, I object to the term "pesticides" as now used by the general public. Including many different types of chemicals under such a broad classification encourages people to consider them as one. Those with even a meager knowledge of these chemicals realize that they differ greatly in their use and potential hazard to the environment.

Most herbicides (chemicals used for controlling weeds) have a very low toxicity to warm blooded animals. If the normal precautions are used, they can be used safely by the applicator and with little potential direct danger to the general population. The great danger in herbicides, however, are in the possible damage caused to desirable plants such as trees, shrubs, ornamentals, and crops. Some of our newer herbicides are extremely potent. A few drops diluted with thousands of gallons of water can kill acres of sensitive crops or ornamentals.

The question has been raised as to whether a University should be making recommendations on the use of pesticides. I feel that we should. Chemical companies are not able to conduct adequate tests on all their products in the various states to enable them to make sound recommendations under all local situations. This is especially true with herbicides which are greatly effected by soil type and climatic conditions. Where can a grower turn for this type of help, if not his land-grant college or university and his local extension agents? This means that an institution like Utah State University must conduct sound research and extension programs in pesticide use if it is to serve the needs of the people of Utah.

LOUIS A. JENSEN is an Extension Agronomist in the Department of Plant Science.
Mechanism of pesticide toxicity

R. P. SHARMA

The primary justification for using pesticides is pegged to the fact that they are toxic to certain target organisms. Somehow they produce physiochemical reactions in functionally important molecules in the living organism. Although the entire support for the use of pesticides depends on their selective toxicity, i.e. they are usually more toxic to the target organisms than to the higher animals and man, such selectivity is only a matter of degree. These chemicals are considered undesirable and/or toxic whenever they come into contact with nontarget organisms such as man and animals of economic and aesthetic value in quantities sufficient to elicit a measurable response.

Unfortunately our present knowledge about the molecular mechanism of such toxic actions is quite limited. In many cases, the toxic mechanisms are related to the manifestation of visible alteration of function or changes in some chemical processes necessary to life. Although this information is an important step forward, more studies are needed. The detailed knowledge of these toxic processes will help establish the rationale of pesticide use and prevent large scale damage.

It may be assumed that the toxic symptoms are manifestations of chemical-biological interactions on a molecular or cellular level. Although there is some relationship between the amount of pesticide ingested or absorbed by an organism, the concentration present at the cellular site of its toxic action depends on several limiting factors unique to an animal species or even individuals within a species.

Before a toxic substance reaches the site of action, it may have to cross several membrane barriers in the organisms or it may be diluted or bound in various organs. Most organisms do have mechanisms to rid themselves of toxic chemicals by detoxification (metabolic pathways) or excretion. A diagrammatic representation of such factors is given in figure 1. Differences in the method of handling toxic chemicals by various organisms are quite often the basis of selective toxicity.

ENZYME INHIBITION

Several pesticides presently in use, including the organophosphorous compounds and carbamates, are inhibitors of the cholinesterase enzymes. These enzymes are widely distributed in various tissues, and their function is to inactivate the chemical acetylcholine which is liberated at the nerve endings to carry signals from one nerve to another. These signals in
turn cause muscle fibers to react. The toxic inhibition of acetylcholinesterases causes an excessive amount of acetylcholine to accumulate and that in turn causes excessive muscular contraction (figure 2). The muscles finally become paralyzed. This interferes with the vital processes such as respiration or circulation and ultimately death results if the cause is not corrected.

Knowledge about the mechanism of toxic action of pesticides has been very useful in determining the preventive conditions of “safe” exposure of humans and domestic animals and curative steps in cases of toxic exposures. The rational treatment of the toxicity of cholinesterase-inhibitors includes the reactivation of the inhibited enzyme (if attempted in time) and the use of acetylcholine antagonists, (e.g. atropine) that will protect the organism from the undesirable toxic effects of accumulated acetylcholine.

DELYED TOXICITY

Although the acute toxic symptoms in the case of organophosphorous insecticide poisons may be described on the basis of anticholinesterase action, these chemicals have some toxic properties that are not related to such enzyme inhibition. Many pesticides of this group have been reported to cause a delayed paralysis in mamalian and avian species. Such delayed action is associated with degeneration and demyelination of peripheral nerves and tracts in the spinal cord. The exact mechanism of such neurotoxic effects is not well known, and studies in this direction are currently in progress in our laboratory.

ACUTE TOXICITY

Many chlorinated hydrocarbon pesticides cause clinical symptoms that are indicative of their neurotoxicity. Experimentally as well as in some accidental cases, members of this class of pesticides cause marked electro-encephalographic changes. These changes are characterized by periodically occurring bursts in the

**Figure 2.** Schematic drawing showing the inhibition of acetylcholinesterase by organophosphorous pesticides: A. In a normal case, the acetylcholine (AC) liberated from the nerve ending may combine with the receptor site (R) at the effector cell to initiate a contraction. The acetylcholine is then hydrolyzed by acetylcholinesterase (AE). B. The occupation of the acetylcholinesterase site by an organophosphate molecule (OP) prevents the hydrolysis of acetylcholine, which then accumulates and causes prolonged contraction that in turn causes paralysis of the effector cell.

**Figure 3.** The influence of dietary dieldrin on brain amine levels in young Mallard ducks. The animals were fed different concentrations of dieldrin in the diet and the brain amine levels were measured at the age of 11 weeks. Note that the three amines—serotonin, norepinephrine, and dopamine—were gradually reduced.
PESTICIDES AS CHEMICALS

WILLIAM A. BRINDLEY

Pesticides are but one class of the many chemicals which pervade and influence our lives and environment. In 1968, the value of pesticides produced in the United States was estimated to be $849,240,000. This included 130 million pounds of fungicides, 318 million pounds of herbicides and plant hormones, and 511 million pounds of insecticides, fumigants, and soil conditioners.

The proper disposition of these chemicals and this large industry is clearly a matter of major public concern. Broad and far-reaching policy decisions need to be made. But who should make such decisions? Who should be given the task of placing pesticides in perspective? What role should various professional disciplines fill in relation to public opinion?

My personal view is that each pesticide must be considered on its own merits and shortcomings—its own potential for pollution or contribution. No individual alone, whether toxicologist, agriculturalist, or ecologist, can do this satisfactorily. Rather, these individuals should be relied upon to contribute the best and most complete information they have to the development of broad policy decisions in the courts and legislatures. The decisions must be political or legal in nature. Only in this fashion, can we hope to make decisions in the best perspective and public interest.

One professional group which will have much to do with development of effective and environmentally safe pesticide technology are the agricultural chemists. This is because pesticides are chemicals, subject to the principles and laws of chemistry and toxicology. Consideration of pesticides from a chemical point of view is essential to properly placing them in perspective.

PESTICIDE TOXICITY

Pesticide toxicity to target and non-target organisms is a principle concern in toxicology. Non-target organisms include those which were not intended to be killed or poisoned by the pesticide application. It is virtually impossible to determine pesticide toxicities for all non-target organisms due, principally, to the large numbers of species which contact any spray residues. Apart from this, however, there are other more specific problems in evaluating pesticide toxicities which must be understood before wise decisions can be made.

WILLIAM A. BRINDLEY is an Associate Professor in the Department of Zoology.
Acute toxicity and chronic toxicity are often considered in pesticide toxicity studies. Acute toxicity, which is the effect in killing animals or plants in a short period of time, is more easily measured. Some acute toxicity data is presented in figure 1. The lower the LD₅₀ dose, the more toxic the compound. The LD₅₀ estimates the dose which would kill 50 percent of the test population. Chronic toxicity differs from acute toxicity in that the time of the test is much longer. Acute toxicity tests last usually a day or less. Chronic toxicity tests may extend for days, weeks, or years and may include studies of reproduction effects, production of deformed progeny or induction of cancer.

The chemical structure can often be correlated with differences in toxicity. Studies of structure-activity relationships are helping to develop selectively toxic insecticides. For example, methyl parathion and Sumithion differ only slightly in structure but Sumithion is nearly 18 times less toxic to mammals (figure 1). Methoxychlor (24 times less toxic) has a similar relationship to DDT.

### COMPLICATING FACTORS

Each of these toxicity tests are complicated by numerous factors and particularly by the experimental conditions which are to be chosen. In many cases, one cannot experiment directly on the species of interest and must substitute other species. Although closely-related species often behave similarly, there are often dramatic differences. For example, carbaryl is very toxic to honey bees, only moderately toxic to alkali and leaf cutter bees, and quite ineffective against house flies.

For some insecticides, the ranges of LD₅₀ values reported are surprisingly large for apparently identical experiments. This is because other experimental conditions are also important but are not often reported in summaries of toxicity data. These include the time the test was done, the sex, age, and nutritional status of the animal, the purity of the insecticide, and other factors. For these reasons, toxicity values cannot be directly transferred from species to species or even from individual to individual in every case. Even greater variations would be found with different routes of administration such as dermal or intravenous routes. These difficulties are compounded many fold when dealing with chronic toxicity.

One difficulty with discussing acute toxicity is that one cannot generalize the results of a few determinations to all members of the class of pesticides involved. LD₅₀ values are sometimes used for this purpose. Parathion, one of the first and most important organophosphorous insecticides is very toxic. Organophosphates therefore have, to many, a reputation for high acute toxicity. Some organophosphates, however, such as malathion, Sumithion, Abate and Gardona have rather low acute toxicities.

### PESTICIDE MOVEMENT IN THE ENVIRONMENT

Pesticides often get into the air, water, soil, or organisms, where their presence and persistence is undesirable. Certain physical, chemical, or biochemical properties govern this. Among these properties are water and fat solubility, vapor pressure, stability to light, weathering or pH, and tendency to be metabolized.

All of these factors (solubility, volatility, stability, and metabolism) relate to the total persistence of a pesticide which man can now only slightly influence by his pesticide-use practices and environmental management. Each of these properties are related to the chemical structure of the pesticide. The relationships are complex and usually only interpretable by a competent toxicologist. Certain examples are discussed below.

### EFFECT OF PHYSICAL PROPERTIES

DDT and dieldrin have very low water solubilities. However, both are readily dissolved in fats and lipids and are absorbed to the organic fractions of soils. DDT is about 923 times more soluble in olive oil than in water. Therefore, in unturbulent waters, much of the residues will be absorbed onto bottom sediments. However, that absorption is too weak to prevent the insecticide from being dissolved in the lipid-containing membranes of animals or the lipid-containing cuticle of plants. Hence, they enter biological organisms from otherwise inert environmental deposits. More water soluble pesticides would be present in the water or absorbed to clay particles.
Other factors may also be important. The tendency for molecules to vaporize into the air is measured by the vapor pressure. Methyl bromide is used as a fumigant because of its very high vapor pressure (1420 mm Hg). Even though the vapor pressures of some pesticides are very low, they can have significant effect upon their loss by evaporation or codistillation with water.

The vapor pressure of dieldrin mixed in a soil has been estimated to be 2.2 x 10⁻⁶ mm Hg (0.0000022) at 20°C and 100 ppm concentration. The vapor density of dieldrin-saturated air under these conditions was 45 nanograms per liter. Despite this low vapor pressure, the principle mechanism of accumulation of dieldrin on upper plant parts was vaporization from the soil and condensation on the leaves. Of course, movement of the saturated air by wind or removal of the dieldrin by accumulation on plant parts would permit more to be volatilized from the soil. Increasing soil temperatures increase the volatilization also. Although significant dissolusion in runoff was less important because of dieldrin's low water solubility (0.25 ppm, 20°C). Water eroding soil sediments did account for significant dieldrin losses.

When applied to the soil surface or the surfaces of buildings, insecticides and pesticides are also subject to the effects of light and weathering. Of course, if the residue is below the surface of soil or water, or in a biological organism, then light, weathering, and vaporization have much less effect. Farmers frequently use this principle to extend the life of the insecticide residue in the field and to bring the insecticide into the region of the plant seeds and roots where soil-infesting insects burrow.

The pH of the environment may also be important. Gardona and chlorfenavinphos have nearly identical structures but different pH susceptibilities. Gardona's half life time at the concentration of 2 ppm, at pH 9.1, 38°C is 37 hours whereas chlorfenavinphos' half life is more than 400 hours under the same conditions. The pH effect would be to completely detoxify the insecticide. Less, however, is known about the quantitative importance of pH factors in degrading pesticides.

**EFFECT OF METABOLISM**

Once in biological organisms, most pesticides are readily metabolized. Most are broken down into simpler and more water soluble molecules which are occasionally more toxic but are more often less toxic or non-toxic. Their elements and degradation products can be transferred in the environment or incorporated into organisms. DDT degradation and metabolism has been widely discussed and sometimes misunderstood in popular literature. Methoxychlor, a related insecticide, presents an interesting contrast.

Contrary to popular belief DDT is often slowly degradable in the environment and is metabolized by organisms. As with many pesticides, soil microorganisms play a major role in degrading DDT. DDT may also be degraded by movement across clay particles or by ultraviolet light. Such transformations usually significantly change a pesticide's properties such as solubility and toxicity.

Yet, DDT is often very persistent in the environment. It and its lipophilic metabolites are passed up food chains by accumulation in the lipid deposits of animals. Highest residues often occur in predatory species and may potentially lead to problems depending on many difficult-to-evaluate factors which are present in any chronic toxicity determination.

Although closely related to DDT, methoxychlor is often more rapidly metabolized than DDT and therefore doesn't accumulate as much in at least some organisms. The remarkable success of DDT in effective and mone­arily cheap insect control has, however, overshadowed the use of meth­oxychlor. As an illustration of this, in 1967, DDT cost 18c per pound and had 334 registered uses. In contrast, methoxychlor cost 66c per pound and had 81 registered uses. Consequently, little basic information is known of methoxychlor's metabolism and environmental accumulation.

**CONCLUSION**

I have only briefly indicated some of the many considerations to be made in understanding pesticides as chemicals. In addition to explaining pesticide toxicity and persistence, chemical and toxicological principles dominate the techniques for pesticide residue detection and analysis. Hence, considerations of pesticide safety and usage policy should be strongly influenced by information from pesticide chemistry and toxicology.

**WILDLIFE NOTES**

The raccoon gets its name from the fact that it washes its food before eating it. The name raccoon is a derivation of the Indian name "arathcone" meaning "the washer."

The use of the words "frog" and "toads" is often confusing. In general, frogs have smooth skins and toads warty skins.

The ribs of the turtle are outside its hip and shoulder girdles — the only vertebrate in which this occurs.

Even though the mole lives underground, its soft fur is so constructed that no earthly stain defiles its glossy smoothness.

Although the lion is called "King of the Beasts," he is not the largest, strongest, or even the bravest member of the animal world.

Fish with forked tails are the fastest swimmers.

Female black bears produce from one to four cubs every two years.

The federal government's first bird study was launched in 1885 when it sought to determine the effects of English sparrows on farming.
REGULATION OF PESTICIDES

From the earliest commercialization of insect pest control based on insecticides, regulatory procedures have been enacted to provide public protection. These acts gradually evolved from the basic provision against marketing sub-standard or mislabelled insecticide products provided by the 1910 Federal Insecticide Act, to the present regulation of herbicides, fungicides, and many other types of agricultural chemicals collectively termed "pesticides." The major United States federal regulation of pesticides is based on two mechanisms—registration of the product and establishment of acceptable levels (tolerances) in foods (table 1).

These procedures, together with certain aspects of control over transporting or mailing chemicals (under the Federal Caustic Poison Act) and regulation of aircraft operations under the Federal Aviation Administration, have served the intended purposes of regulating the agricultural chemicals industry, protecting the safety of the food supply, and preventing the occurrence of secondary problems (such as contamination of animal feeds) within the agricultural industry, itself. Unfortunately, this legislation has not demonstrated an equal capacity to adequately protect the general environment.

The purpose of this article is to briefly outline the concepts in these regulations and consider the desirability of suggested modifications.

Registration of a pesticide product is required under federal law, and additionally by each state, as a condition for its marketing. At the federal level, registration involves judgment of efficacy, absence of public health hazard, suitability of the product label in terms of directions for use and warnings pertaining to safe use. The specific criteria for judgment have steadily evolved since original enactment of the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA) in 1947. Administration of that act was placed in the Department of Agriculture. However, from the outset, the Public Health Service (HEW) and the Department of the Interior became involved as advisors from the standpoint of human safety and expected impact on fish or other wildlife. Administration of all this was reorganized in 1970 by placing the entire judgment (of efficacy, safety to man, wildlife, and the total environment) in the hands of the newly formed Environmental Protection Agency (EPA), although with no substantial changes in the concept of registration. But changes in registration philosophy can be anticipated since at this writing (June, 1971) Congress is considering several possible revisions of FIFRA.

Each state also requires pesticides to be registered under individual state acts. The criteria and conditions involved under these acts, however, rarely differ from those at the federal level. Most states, like Utah, cannot possibly pursue an independent evaluation of every pesticide product, and, therefore, generally register any product requested by the manufacturer that bears a valid federal registration.

While the registration concept as outlined may seem to cover the needs of society in regulating pesticides fairly well, experience has shown serious deficiencies. The problem is that the registration process serves mainly to provide order in the pesticide industries. This is obtained through the efficacy requirements, standardization of labels, and general procedures to regulate marketing. But the public is not provided with any selective judgment about the suitability for use of any one product among a group of pesticides having similar effectiveness. This is because any applicant's product must be accepted for registration if it meets the various criteria laid down. Following this, the product's practical value then becomes a result of the market place, where often price alone dictates its acceptance and usage. It is no accident that DDT has been by far the most widely used insecticide. That was the simple consequence of its broad effectiveness and its very low cost and apparent safety in comparison to other products.

Closer to the ideal would be a registration (marketing regulation) system with more selectivity utilizing some mechanism for favoring those pesticides which are functionally and ecologically superior. Under the pending federal legislation this would be reached, in part, by a classification system for all pesticides which would place them into categories based on health hazard and environmental stability. Separate rules would then apply to the marketing and permitted uses of each class.

Another weakness of the present regulatory procedure lies in its awkward provisions for removing a product from the market if that becomes necessary or advisable after registration approval is once gained. The EPA Administrator has the authority to cancel or to suspend any pesticide registration. These two terms refer to distinctly different procedures. Cancellation, which has been more frequently used, begins with public notification by the administrator of his intent to cancel a registration. The manufacturer then has 30 days in which to acquiesce or file a formal

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Many have accused the USDA of excessive timidity or of being overly influenced by the chemical industry, in failing to bring more recall actions against those pesticides claimed to be especially detrimental to the environment. Without passing judgment on those charges, it is appropriate to mention that administrators of FIFRA consistently overlooked use of the one advantage provided to the public by that otherwise one-sided piece of legislation. FIFRA specifies a 5-year period of registration, after which a renewal must be procured. This renewal requirement could have provided for an orderly review and retirement of outmoded or undesirable products. As administered, however, the renewal process has tended to be a routine matter simply requiring reapplication without additional justification and evidence of safety being required. Consequently, registrations of older pesticides were maintained and renewed while new products were required to meet increasingly stricter requirements in order to obtain registration.

Pesticide tolerances in foods are established under the federal Food, Drug, and Cosmetic Act (as amended, 1954) and constitute the second major means of regulation. Under that act a raw agricultural food commodity, such as milk, is condemned if it contains a pesticide residue in an amount exceeding a defined tolerance.

Tolerance values are established after consideration of extensive toxicology data. Required are short- and long-term toxicity data obtained with at least two animal species, extensive biochemical studies to establish the degree of absorption, distribution in the body, transformations of the pesticide to other products in the body, elimination by the body, and evidence of effects on enzymes. Reproduction studies with animals treated with the pesticide are also required as is any direct data obtained from observations of humans, such as might accrue from health records of chemical workers.

Provided with such data and detailed information on the use for the pesticide and the probable residues resulting from practical use, the Secretary of Health, Education, and Welfare may determine that a “negligible residue” tolerance is appropriate. The negligible residue tolerance is based on evidence that the levels of pesticide intake through food would be so slight as to be of little or no toxicological significance. If, however, the pesticide cannot be used in producing the crop without an appreciable residue (a residue in excess of negligible) than a finite tolerance may be established for a special crop (e.g., 1 part per million of parathion on asparagus) on the basis of estimating the quantity of that pesticide humans could ingest daily without toxic effects and the amount that crop would provide to a person making liberal use of the food in his diet. The tolerance value is set to provide a large margin of safety based on these estimations.

It is important to note that tolerances for pesticides are not established unless applied for and are then set only for specific crops. If raw agricultural commodities are discovered to bear pesticide residues for which there is no tolerance, or if the residue level exceeds the established tolerance value, the commodity is condemned for interstate marketing.

The Food and Drug Administration, and also state agricultural and health officials, regularly pick up agricultural samples for pesticide analysis. Threat of seizure and condemnation of a crop for unlawful residues constitutes the most powerful control over pesticide usage we possess. This fact certainly deters most growers from careless use of pesticides. It causes the large canning and food processing corporations to supervise pesticide applications to crops contracted by them. It causes fruit and vegetable shippers to check their sources carefully lest an entire trainload, as has occasionally happened with potatoes and other perishable commodities, be impounded for thorough sampling after an inspector found high residues in a few spot samplings. It causes dairymen to carefully check the origin of hay and other
feeds they purchase since their milk may ultimately reveal the fact of high residues in the feeds.

Controlling pesticide usage in this indirect manner, while generally effective in safeguarding our food supply, is really quite inadequate since it allows the possibility of the cotton farmer, the home gardener, the shade tree specialist, the exterminator, the mosquito abatement district, and many others to make relatively indiscriminate use of any pesticide they can purchase.

Beyond the registration process and enforcement of tolerances for pesticides on agricultural commodities, we have no real means of regulating the use of pesticides. Our only recourse has been persuasion, persuasion in the form of recommendations to users on what pesticide to select, how often to apply it, and so-forth. (Regulation is not quite so weak as this when the user is a hired commercial applicator since most states require them to be specially examined and licensed.)

Our history of pesticide usage has clearly shown inadequacies in our control system. Human nature tends to defy complete voluntary compliance with recommended procedures and the regulatory laws permit too much individualism by users. That the environment has taken some punishment as a result is undeniable. Perhaps even more serious, however, is the casualness with which the public entrusts highly toxic chemicals to be made easily available to any buyer in virtually any amount, and the indifference to any but the most immediate con-

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<td>1947—Insecticide, Fungicide, Rodenticide Act (FIFRA), 7 U.S.C. § 135 <em>et. seq. as amended</em> (1964).</td>
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<td>1959—Nematocide, Plant Regulator, Defoliant, and Desiccant Amendment to FIFRA, Act of Aug. 7 1959, Pub. L. 86-139, § 2, 73 Stat. 2861.</td>
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<td>1964—FIFRA amendment, Act of May 12, 1964, Pub. L. 88-305, § 1, 78 Stat. 286.</td>
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<td>1954—Federal Food, Drug, and Cosmetic Act § 346 (a), ch. 25, § 408, 68 Stat. 511 (1954), <em>as amended</em> 21 U.S.C. § 346 (a) (1964).</td>
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sequences that such policy instills in the user.

Legislation now pending in Washington recognizes the need for better regulation of pesticide use, and we can quite confidently expect some marked changes in the control procedures. The expected major new provision will place pesticides into general or restricted use categories with associated labelling and packaging requirements. With revised federal legislation now developing, the states will need to quickly refurbish their control regulations as well.

Utah is fortunate in having available, under the provisions of the 1971 Legislature's Pesticide Control Act, a fairly flexible regulating procedure. It empowers the Utah Pesticide Control Committee to authorize specific regulations governing pesticide registration and usage. The Committee's regulations can be local or statewide in scope, timed for optimum value to user and protection to the public, readily modified as special needs or problems materialize and, in short, constantly updated for maximal effectiveness. This very flexibility, however, could also become a grave handicap should the Board's regulations become too permissive on the one hand that the public interest and safety is jeopardized, or too restrictive and capricious on the other hand that necessary pesticide uses in agriculture and other vital areas are not possible. It is, therefore, most important that the public be continuously involved in the procedures of the Pesticide Control Committee and informed of its actions. Without such public participation it is unlikely that Utah can seriously attempt to improve upon its presently minimal control of pesticide usage and assume its proper role in the nationwide regulation of these significant chemicals.

**Alternatives to chemical control of pests**

DONALD W. DAVIS AND TING H. HSIAO

In discussing the alternatives to chemical control of pests, we are faced with the problem of semantics. Some people wish to abolish pesticides as a means of control, while others try to reduce the amount of pesticides used and eliminate the major problems associated with their use. Most persons associated with the problem of pest control in agriculture and forestry do not visualize the elimination of chemical pesticides, but we see many ways of improving our present practices.

**BASIC APPROACHES**

Basically, we have about nine approaches to the control of insect pests. The relative emphasis varies with the pest involved and with the circumstances under which the pest occurs. These approaches are:

1. Chemical control.
2. Biological control using parasites, predators and pathogens.
3. Cultural practices, including land and water management.
4. Mechanical and physical devices to attract, repel or kill insects.
5. Sterilization and genetic manipulation.
6. Manipulating insect behavior through sex pheromones, attractants and repellents.
7. Breeding insect-resistant plant varieties.
8. Manipulating insect biology through hormones.
9. Quarantines and other practices to prevent insect introductions.

Of these nine approaches, number 8 is largely theoretical, while all others are in actual use. We expect no major changes in these basic approaches, but we do expect some major changes in the relative emphasis. For example, there will probably be a much more refined use of pesticides, with a great deal of emphasis on integrated control.

Insect problems arise when damage exceeds the acceptable market standards. We often call this an economic injury level. This level varies with the type of crop or product. If the injury occurs to the portion to be eaten by people, then there is virtually no damage allowed. Most fruits and vegetables fall into this category. Where the health of the plant is involved, but the edible portion not damaged, or if the product does not enter human food channels, then a certain amount of pest damage can be tolerated. One possibility for reducing pesticide use would be to increase the amount of pest injury allowed on marketed produce.

We really have two concepts in pest control. We either attempt to lower a general population level of a pest, or we use a drastic or direct approach in an attempt to eliminate the pests in a given area.

Insect populations always fluctuate both within and between seasons. The population management approach lowers the general level of this fluctuating population and usually prevents the occurrence of epidemics. Biological control, cultural practices, and plant resistances are examples of this approach. On crops with a liberal economic injury level, population management alone may give adequate control. It is not adequate on most fruits and vegetables. In biological
control, it is axiomatic that survivors must be left. A predatory insect could not have evolved had it been 100 percent effective in killing its hosts.

**CHEMICAL CONTROL**

In the direct chemical approach to insect control, there can be nearly 100 percent effectiveness. Pesticides have been able to do this, and more recently control through sterilization has succeeded. In most fruits and vegetables, chemical control has been the only means available for high control levels. There is another factor which forces the excessive use of pesticides. We pride ourselves in the fact that only 17 percent of our income is spent for food compared to more than 50 percent in most countries. Of this 17 percent, only about half reaches the farmer. Farmers receive less return on their investments and less income per hour of work than any other major industry in the country. To survive, they must use every method available to increase efficiency. Pesticides, of all types, account for about 30 percent of the crop yields, and fertilizers for another 30 percent. Chemical control has its weaknesses, however. Pests demonstrate remarkable immune responses in successive generations. This requires the constant development of new pesticides with resultant added pollution possibilities. In addition, many helpful insects (predators and pollinators) are killed along with the target populations.

**BIOLOGICAL CONTROL**

About 40 years ago, there was strong animosity between entomologists advocating chemical control, and those advocating biological control. It was an 'either-or' proposition. Unfortunately, this same 'either-or' idea exists in the present ecology movement. Some fail to realize that it is impossible, within the realm of our present knowledge, to obtain adequate pest control by biological means alone. Those that advocate it are being naive and show a lack of both biological and economic knowledge. Many pests, particularly insects such as grasshoppers, lack effective natural enemies. Biological control is also weak where extreme seasonal fluctuations occur. After a period of low insect numbers, there is a definite delay before parasites and predators can achieve effective control. During this lag, there is often extreme damage.

On the other hand, the many forces of nature, including parasites, predators, and climate, account for about 99 percent destruction of potential insect numbers. Something must happen to 99 out of every 100 individuals to maintain an insect population at an average level. This value is impossible to estimate and we should do all in our power to preserve it.

Biological control is the manipulation by man of the natural control factors. Some of the ways in which this can be done are:

1. Introduce new parasites and predators from other areas.
2. Adjust cultural practices to encourage natural enemies.
3. Collect or rear beneficial insects for mass distribution.
4. Rear beneficial insects for release where they cannot survive the winter.
5. Modify the micro-climate to encourage epidemics of insect pathogens.
6. Distribute disease pathogens which attack insect pests.

The least developed phase of biological control is the use of diseases of insects. Viruses, in particular are highly effective and give better control than other biological control methods. Two problems have prevented their use. There is no specific method to analyze for insect viruses, and there will probably be many objections from the public should it become known that food is being treated with viruses. The reaction could possibly be greater than the present fear of pesticides.

**INTEGRATED CONTROL**

In short, chemical control is fast and complete, but is only temporary and has many undesirable side effects. Biological control is relatively permanent, creates very few side effects, but is slow and incomplete. The strengths of one method are the weaknesses of the other. Integrated control attempts to use the strengths of both methods at the same time, while minimizing the weaknesses. Biological control is established as the prime or foundation approach, with the use of chemicals worked in without upsetting the beneficial parasites and predators. Initially, integrated control referred to the integration of chemical and biological control, but later all aspects of control were considered in the integration. Some people prefer the term "pest management" for this total integration.

Traditionally, with chemical control, the idea has been to hit all pest populations as hard as possible with the most potent chemical available. This was repeated whenever a pest population started to build up. In the absence of natural enemies, the potential build-up of pests was astronomical. In cotton, 10 or more applications were made each season. Many previously minor pests, in the absence of natural enemies, became important. Once a pest control program was started, you were committed to continue it for at least the entire season.

With integrated control, the main concern is full utilization of all population control methods. Pesticides must augment biological and cultural controls. Careful attention must be given to all pesticide use, so that a minimum amount of damage is done to natural enemies. This is done through careful timing of applications, spraying restricted portions of the crop, using minimum rates, using short-lived pesticides, and selecting materials which tend to be specific against the pests. All of these methods are never available in any given situation.

Integrated control is, in essence, applied ecology which attempts to meet the economic necessities of agricultural production. As an ecological approach, it requires vast amounts of information on each agro-ecosystem. Unfortunately, the pest problems are
too variable from one part of the country to another for direct transfer of an integrated control program. During the season there must be constant sampling and supervision. Some workers believe that a system analysis approach is necessary. Here in Utah we now have a workable integrated control program being used by about 25 percent of the apple growers. As with any practice there are both strengths and weaknesses.

Some strengths of integrated control are:

1. There is much less total pesticide use.
2. The pesticides used are generally short lived.
3. It is ecologically oriented.
4. Minor pests rarely develop into economic pests.
5. It prevents the development of resistance to pesticides.
6. It preserves predators, parasites and pollinators.

Some weaknesses of integrated control are:

1. Extensive biological information is needed, but not always available.
2. Trained personnel are needed for supervision.
3. Some pest injury must be tolerated.
4. Pesticides must be timed and applied accurately.
5. Other agronomic practices may interfere with the integrated program.
6. Selective pesticides are not always available.

**STERILIZATION TECHNIQUES AND GENETIC MANIPULATION**

The manipulation of the reproductive processes of pests for their own destruction, is a relatively new approach to insect control and it holds considerable promise. Two methods are currently under extensive investigation, one of which has been used successfully. These are sterilization techniques and genetic manipulations. The sterilization method is based on rearing massive numbers of a pest species, sterilizing them with either radiation or chemosterilants, then releasing them into a population to compete for mates. An alternate method being developed, involves the use of chemosterilants directly to field populations through the use of powerful attractants such as sex pheromones. The treated insects then disperse to mate with the non-sterilized individuals. Genetic manipulation by means of hybrid sterility, cytoplasmic incompatibility, translocation, and introduction of deleterious genes is still in the developmental stage, but it seems to have the potential of reducing insect populations to low levels.

The advantages of the sterilization techniques are their rapid results, with the potential for eradication of insect pests within a relatively few generations. The method is highly selective, involving only the target species, leaving the rest of the ecosystem relatively undisturbed. Immunity to the sterilization method of insect control is unlikely to develop.

The sterile-male-release technique has been used successfully in the eradication of the screwworm in southeastern United States in 1959-60, and is being attempted in the southwestern states at present. This pest formerly cost livestock producers an estimated $120 million annually. The total eradication program is costing about $6 million per year. A similar method has been used with the Mediterranean, and other related, fruit flies with considerable success. Intensive research and field trials are now underway with several major insect pests, including: pink bollworm, boll weevil, codling moth, gypsy moth, mosquito, tsetse fly, and bark-beetle.

The sterilization and genetic methods for insect control are attracting much interest among biologists, but before such methods can be developed for practical use, a thorough knowledge of the biology, ecology, and population dynamics of each target insect must be available. In addition, an economical method of mass-rearing is necessary for those procedures calling for laboratory sterilization and field releases.

**THE USE OF ATTRACTANTS AND REPPELLENTS**

One of the newer developments in insect control is the use of chemical stimuli that regulate insect behavior. These stimuli can be by sex pheromones, attractants, or repellents. Sex pheromones are chemical substances produced and released by one sex to attract or elicit some response, usually mating, from the opposite sex. Attractants cause a positive olfactory response, and repellents cause a negative response. Repellents can be used as preventative measures, but not as direct control agents.

Sex pheromones and attractants are the most useful. One advantage of sex pheromones is that they are highly specific and can be used in infinitesimal amounts. The most potent attractants, other than sex pheromones, can elicit responses up to 1/4 mile, while some sex pheromones have been effective up to several miles.

Direct use of pheromones or attractants for insect control, through the modification of their behavior, is possible in at least two ways. Both approaches require an extensive knowledge of insect behavior and physiology. (1) They can be stimulated to approach a trap or other method of control. One method widely used at present, is to survey the presence or abundance of a pest species and to evaluate insect control programs. (2) Their behavior can be inhibited or confused. One method is to saturate the atmosphere with pheromones so that the insect orientation toward the opposite sex becomes confused. Pheromones and attractants also can be combined with chemosterilants, insecticides, or physical methods of control.

Intensive research efforts are being devoted to the isolation, identification and synthesis of sex pheromones. Over 200 insect species, including several prominent pest species such as
gypsy moth, pink bollworm, cabbage looper, and boll weevil, in all major orders possess them. More than 20 of these pheromones have now been identified.

Trimedlure, cue-lure and methyl eugenol are synthetic attractants of the Mediterranean fruit fly, melon fly, and Oriental fruit fly, respectively. Methyl eugenol was used to eradicate the Oriental fruit fly from the Pacific island of Rota. The attractant was mixed with the insecticide naled, and incorporated into small squares of fiberboard for distribution by aircraft. Trimedlure and cue-lure have been used in fruit fly survey work.

INSECT-RESISTANT PLANT VARIETIES

Crop varieties which are naturally immune or substantially resistant to insect attack provide an effective method for insect control. The advantage of using insect-resistant varieties is that they impose few undesirable effects on the environment. These varieties generally are substituted for susceptible varieties of the same crop, and the effects are primarily against the particular pest for which the resistance was developed. Insect-resistant varieties are obtained by four general methods,

1. Introduction of foreign varieties which already possess a higher than usual level of resistance to a given pest.

2. Exposure of plants of a given variety to pest infestations, followed by a selection of the surviving plants to be used for propagation.

3. Hybridization of resistant non-economic strains with commercial non-resistant varieties, followed by the selection of desirable recombinations.

4. The induction of new mutation through exposure to radiation on mutagenic chemicals.

The breeding of insect-resistant varieties is a costly and time consuming process. It requires continued cooperation of plant breeders and entomologists, and it normally takes from 5 to 15 years to develop a commercially acceptable resistant variety. A variety developed to resist one pest (complete immunity is very rare) does not usually carry resistance to other pests, therefore, chemical control is actually not eliminated for that particular crop. The physiological requirements are not the same for all insects. These factors have contributed to the slow development of resistant agricultural crops.

Many insect-resistant varieties of crops are now being grown. Leafhopper and spotted-alalfa-aphid resistant varieties of alfalfa, such as Vernal, Lahontan and Moapa have been developed. Corn varieties resistant to the European corn borer are grown in the Midwest. Wheat varieties resistant to the Hessian fly and the stem sawfly are commonly planted in USA and Canada. It has been estimated that the combined cost to develop the above mentioned varieties was $9.3 million. The annual saving has been about $308 million.

INSECT HORMONES

The potential of using insect hormones for pest control has been partially revealed by studies of insect physiology during the past two decades. Several hormones are responsible for the control of growth and metamorphosis of insects. The brain hormone stimulates the prothoracic gland to secrete another hormone, ecdysone. The action of ecdysone causes insects to molt. Another hormone, the juvenile hormone, is secreted by the endocrine gland—corpus allatum. When large amounts of juvenile hormone are present during molting, larval characters are preserved. In the absence of juvenile hormone, the insect molts into the adult stage. Applying these hormones to developing insects interferes with metamorphosis, molting, embryonic development and reproduction. They also are effective in minute doses, another distinct advantage.

These compounds have now been synthesized and other substances with hormone-like activities have been discovered. Because of the differences between the control mechanisms of higher animals and insects, it is assumed that these insect hormones would have no adverse effects on higher animals. However, most of the hormones and mimicking compounds are not species specific. They affect all insects regardless of whether they are beneficial or destructive. More research is needed to develop the potential of insect hormones for insect control.

CONCLUSIONS

During April of 1970, a conference on pest management was held at Raleigh, North Carolina. Three basic conclusions were drawn from these meetings.

1. The pest management approach is both biologically and economically sound in agriculture and forestry.

2. For pest management to be effective, vast amounts of biological data are needed and the program must be supervised by trained personnel. This will require much more money than is available now.

3. The chances of getting the additional money in the near future are virtually nil.

We wish to make it very clear that, alternatives to the traditional methods of pest control are expensive to develop. All sorts of ecology oriented groups have criticized the present methods of pest control, but none have offered the necessary money to develop alternative approaches. The entire outlay related to controls and basic studies of economic insects affecting both agriculture and forestry by both the USDA and Agricultural Experiment Stations, amounted to about $50 million in 1970. The direct costs of the recent Apollo moon shot were about $500 million, or enough to support the present insect studies for 10 years. We as a nation, should give some very serious thoughts to priorities and decide how seriously we want to reduce pesticide use.
PESTICIDE USE OR NON-USE

Economics as a basis for policy decisions

ALLEN LE BARON

No one can deny that there have been widespread social gains from the introduction and use of pesticides. The obvious and direct benefits to the health and welfare of human, animal and plant life through anti-malarial campaigns, disease controls or through improved food quantity are well known. Private economic benefits to farmers and householders have also been great. Otherwise, adoption of new pesticides and herbicides on a worldwide basis would never have occurred. At the same time, there is now a general recognition that widespread pesticide use entails a clear risk of harmful side effects to plants, animals, soil, water, and humans.

Any discussion of the "pesticide problem" must be in terms of the "trade-offs" between benefits and risks—society cannot have one without the other. It is probable that through research, educational programs, and the like, various modifications can be introduced in the technological links between benefits and risks, so that certain trade-offs may be made more acceptable. And some progress in reducing the risk/benefit ratio is the obvious need, for this is what the fuss is all about—some segments of society are saying that certain benefits do not justify the risks or social costs.

ECONOMIC PERSPECTIVE

Given our current knowledge about the technical relationship between pesticide benefits and costs, we can differentiate three general patterns of trade-off acceptability: (1) in many underdeveloped nations, there is a general public effort to introduce pesticides into farming technology to capture production benefits; (2) most types of public health or nuisance campaign seem to be favorably supported, since both public benefits and costs are widely diffused; (3) application of massive doses of pesticides, based on private responses to conditions in the marketplace of well-to-do countries, is becoming less and less acceptable. What follows is directed to the third situation.

The United States is a big country, with a large population, a high standard of living and a lot of agriculture. Pesticides and herbicides are relatively cheap as compared to other input factors, and farmers and homeowners place heavy reliance on them. This increases the probability of observing spillovers or special social costs due to pesticide use. Some groups in our society view these external effects as negative on balance and costly. At the same time, it is observed that farmers and householders do not always bear these additional costs. Farmers especially are in a position to avoid bearing all the social costs of their pesticide decisions. This is the reason why heavy pesticide use in the United States' private sector has been tagged as one aspect of the "pesticide problem."

Economists view the occurrence of pollution as a manifestation of market breakdown. For example, individuals are only able to make air and waterways dumping grounds because others do not own them or because others cannot enforce what property rights they do have. This free use of sometimes unowned resources imposes costs or external effects on third parties. It may be true that such free use is less deliberate or is indirect in the case of pesticides. Nevertheless, the end result is the same: third parties are harmed and the costs of such harm are not borne by individual instigators.

This suggests why economists look so much toward markets. In general, we can assume that the market price of an item bears some close relation to the opportunities foregone by society resulting from failure to use the resources embodied in the product to create something else. Thus the resource allocations automatically achieved through market forces are taken, in the first instance, to be beneficial to all of society and to indicate socially desirable levels of factor usage in various processes.

But automatic market forces do not take into account spill-overs, third-party effects, diseconomies or whatever it is we choose to call external technological effects. Indeed, normal market forces will lead private parties to devote or allocate too many resources to activities creating negative external effects. This is because the firms or individuals causing pollution absorb only that portion of the total social cost as indicated by the marketplace. Suppose a given farmer had to include, in the price of the pesticide, an additional increment equal to the costs of subsequent negative external effects? Less pesticide would be used and output would fall. In figure 1, the additional value of killing crop pests (V) is plotted

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against the additional costs (C) of increased pesticide input. Market forces will cause level OX to be employed. If pesticide external effects costs are added (C+E) and paid for by the agricultural sector, only OX' pesticide will be used. If there are some spillover social benefits that should be added (V+B) the "best" output will be OX'' level of pesticide use, but this level will not be achieved unless these added benefits can somehow be captured by the farmer.

These notions are straight-forward. What are some of their implications?

1. We may not be completely certain about the shapes or locations of the solid function (V&C).
2. We have little knowledge about social benefits from pesticides (B).
3. The magnitude of negative external effects (E) is unknown.
4. The methods of valuing B&E are weak.
5. The substitution rates of pesticides for other agricultural inputs are unknown or partially unknown.

**DATA REQUIREMENTS AND SOME INTERPRETATIONS**

Behind V&C lie other relationships, specifically the demand for agricultural products and production functions relating farm outputs to inputs. To the degree these latter relationships are known, we may imagine the possibilities of estimating that part of social benefits and costs of pesticide policies that would be reflected in the market place.

The key requirement is some knowledge of supply-demand relationships for agricultural commodities. There is a danger in simply measuring crop increases or decreases due to pesticides and valuing the increments by money prices. One possibility is that the wrong prices will be employed. An individual farmer might be right in using market prices, but if pesticides raise every farmer's output prices will fall. Farm revenues in total will be affected not only through greater sales, but there also will be lower receipts per unit. Total farmer revenues may actually fall. Many food consumption studies have shown that a 1 percent increase in crops marketed will lead to more than 1 percent decrease in price.

Current market prices may invite misleading valuations of pesticide agricultural or household benefits if they do not allow for government intervention or price supports and their distorting effects on markets. Two examples will make this clear. Figures 2 and 3 show known national demand and supply functions for some crop. They are labeled D-E and A-S respectively. Introduction of pesticides is a technological advance that induces farmers to supply more of the crop at all prices, thereby shifting the market supply to the right, B-T.

In the first situation (figure 2) there is a system of direct price supports combined with no acreage restrictions. Before introduction of pesticide, or the government program, market forces would lead to price, O-P and output, O-Q. If the support price is O-C, the public will only buy O-W, even though amount O-R is produced. The difference, W-R, goes into storage. The social costs of the resources used (as measured by the market) are OAMW, while the social value of the benefits are ODW. But when the pesticides are introduced output increases to O-X, at an overall social cost of OBGX. The benefits are unchanged.

This shows why there is often a need for acreage controls combined with direct price support. Suppose each control holds output at the demanded (O-W) level at social cost, OAZW, and a net benefit, ADMZ. Then introduction of pesticides would not only reduce costs to OBJW, but net benefits would increase to BDMJ (originally ADMZ).

In the second situation (figure 3) there are no price supports but effective per unit returns to the farmer are held at level O-C by a system of transfer payments or income subsidies so that consumer prices are free to seek their own levels. If farmers supply O-R quantity, free market prices will only clear the quantity at level O-H. Gross benefits will now be greater, ODNR, while costs will be
Figure 2. Evaluation of introducing pesticides in production of a price supported (by government purchase) crop.

Figure 3. Evaluation of introducing pesticides in production of a crop linked to income transfer payments.

OAIR (unchanged from direct support plan). With the introduction of pesticides, and no acreage controls, output will jump to OX, but the market clearing price will fall to OB. Thus social gross benefits will increase to ODKX, which represents considerable improvement over the first situation.

It is clear that the gross benefits and costs or alterations in their magnitude, due to introduction of pesticides, are controlled not only by the shapes and locations of the market supply and demand functions, but by the method employed in supporting or raising rural incomes. Thus numerous other “outcomes” could be postulated. In addition it is relatively simple to make some conjectures about the shares of gross benefits that will accrue to consumers, entrepreneurs and input factors. There is also some hope of obtaining estimates of the functions in question. Thus, in areas where monetary values serve as resource allocators, we do have some framework for analyzing social welfare effects.

Non-market objectives are not so readily conceptualized or handled. Measurement problems are much greater when we consider evaluating the effects of pesticides on human health or fish and wildlife. We may well wonder if there is any method of bringing non-market objectives, such as better health, into the calculations. There is wide disagreement over general viewpoints:

1. Use ingenuity and persistence to find some common denominator that will fit into the “market objectives”;
2. Simply provide decision makers with appended discussions in qualitative or quantitative and let them make the decisions or do the balancing;
3. Value according to the loss or sacrifice in market objectives required to raise or achieve non-market ones;
4. Values for non-market objectives are implied in past decisions since we can compare what would have happened without the imposed decisions of policy makers.

It is not our purpose to select the right criterion but it may be noted that various attempts to place values on reduction and mortality have been made. The most widely employed method values human life in terms of the productive value of present and future labor potential.

Even if we accept such a scheme we must still await the results of developing functional relationships between pesticide usage and pesticide intake by humans and the associated levels of mortality and morbidity. Pretty much the same conclusion holds for fish and wildlife, especially where toxic effects are involved. The special problem in this case revolves around the difficulty in obtaining an index of aggregate valuation of all the species conceivably involved. Some species benefit at the same time others are harmed.

Supposing somehow that, in terms of figure 1, E+B could be measured, even if the functions V+B and C+E could not be specified. Then some "guidelines" could be employed such as:

1. Suppose E O. If the same level of positive benefits can be obtained by other pest controls having lower E, use of the latter can be encouraged by administratively raising pesticide prices.
2. If (B+V) C+E, (no substitution and controls possible) can be imposed except in selected cases.
3. If new controls or chemicals can be developed at a capitalized research cost E, such research could be encouraged.
4. If it is high due to ignorance of alternatives or ignorance about proper use of chemicals, policy can be directed to educational and regulatory programs.

Naturally one assumes that administrative actions encouraging artificial, high pesticide prices or use prohibition would not be undertaken in the absence of exploration of alternatives. The main alternatives are to prevent introduction and spread of pests; good cultural practices and sanitation; use of natural enemies of pests; resistant plant varieties; preemptive sterile insects; and changed controls on allowable ways to use pesticides. Most of these options have their own sets of difficulties or hurdles.

CONCLUDING OBSERVATIONS

There is no way to escape the need to resort to valuation in the process of setting pesticide policy. Some persons would prefer not to have assign values to illness, a human life, a bird, a fish, etc., partly, it appears, because they feel that any direct method does not exist. Certain plausible "back door approaches" are possible: for example the cost of eliminating an adverse effect by developing an alternative or the estimated sacrifice in positive measurable benefits by decreasing the level of use.

Besides valuation, some account must be taken of probabilities of an unwanted occurrence such as a large-scale increase in cancer due to ingestion of chlorinated hydrocarbons. Potential pesticide effects need to be weighed with such probabilities. This suggests one line of needed ecological research. Obviously there are numerous other researchable relationships that should be investigated.

Policy dominated by special interest groups may be dangerous. An elimination of all spill-overs may not be the most economic policy in terms of resources or national values. Pesticides have been built into agricultural technology and it will not be easy to change policy without reversing recent advances in farming methods.

Tremendous uncertainty springs from the use of pesticide chemicals by millions of individuals, from contact with these chemicals and their residues by other millions of organisms, and from the multitude of purposes to which the chemicals are put.

There is no hope of observing the levels of use and the positive or negative effects for each organism or set of organisms affected. It is unlikely, therefore, that any policy can be formulated which will deal with these chemicals on the basis of making some of society better off while none are made worse off. Most likely policies will benefit some at the cost of others and all losers will be hard to identify and compensate.

Research activities are needed that will tend to simplify the complexities of the real world and bring some order out of chaos. Let us work on the most serious aspects first as determined by all related disciplines acting in concert. First locate the sources of contamination by pesticides where payoff from control is greatest. Also identify marginal payoffs.

Second, match whatever evidence is available concerning adverse effects with the sources of contamination and give research priority to control and reduction of adverse effects in areas where large benefits from pesticides seem to be related to large external effects as measured by whatever criteria are available. For areas where rather small benefits from pesticide use appear to be associated with sizable spill-overs, assign a lower priority, etc.

<table>
<thead>
<tr>
<th>Pesticide/Herbicide Type</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Costs</td>
<td>Low</td>
</tr>
<tr>
<td>Low</td>
<td>4</td>
</tr>
<tr>
<td>High</td>
<td>2</td>
</tr>
</tbody>
</table>

Do this for all sources of contamination. This matrix of rankings sets the stage for second round research of interdisciplinary character. Since the costs of ecological system studies is high, preliminary research priorities are necessary.
Pesticides and non-target insects

G. E. BOHART

Broad spectrum insecticides, which may leave a field nearly devoid of insect life are usually easier to sell the farmer than are more selective materials. For example, in blossoming alfalfa seed fields, the farmer is usually pleased to note that following the application of certain broad spectrum insecticides such as dieldrin or parathion, his veritable zoo of insects has disappeared. What he usually does not know is that most of the species present in his field before the applications were beneficial as biological control agents, and that their destruction is likely to result in a resurgence of the pest species. Although additional applications may take care of the problem of pest build-up, he should strive for fewer rather than more applications to protect his plants.

Selective materials, if properly chosen, reduce the population of target insects to sub-economic levels without causing excessive damage to beneficial species. If the application leaves a small population of the pest species, the result may be better than if they were not completely destroyed, especially if biological control agents are known to be present. In this case, the agents are not only preserved, but can maintain themselves on the remaining host insects and thus prevent a destructive second infestation. Unfortunately, on many crops, the existing emphasis on complete freedom from insect parts and insect-caused blemishes is incompatible with preservation of biological control agents.

Non-target insects destroyed by the broad spectrum insecticides usually include insect pollinators as well as biological control agents. Destruction of pollinators, even on a crop that does not require insect pollination, may reduce the yield potential of neighboring crops that do. In addition, if the pollinators are honey bees, the livelihood of the beekeeper is threatened.

Pollinators are also seriously affected by herbicides applied for the control of weeds. There can be little argument against the control of weeds in cultivated fields or of certain "noxious" perennials wherever found. However, the advantages, if any, of indiscriminate roadside spraying to suppress or eliminate broad-leaved plants should be weighed against the aesthetic values involved as well as the pollinators (including honey bees) which often depend to a large extent on roadside flowers. In many areas, particularly in our western valleys, bloom is heavily concentrated along roadsides as a result of rainfall run-off. Most of the plants involved are not "noxious" and their presence or absence along roads and in "waste" places has little if any effect on infestations by the same species in cultivated fields.

In recent years investigators have placed increasing emphasis on the "integrated control concept." Another expression embodying essentially the same concept is "pest management." Both expressions refer to control of pest populations by means that cause as little damage as possible to natural control processes and to the general environment. In accordance with this concept, all essential features of the ecology of a crop and its associated organisms in an area are studied to determine the effects of attempts to reduce the populations of pest species.

In the integrated control concept, the greatest possible advantage is taken of biological control agents (parasites and predators) and of cultural manipulations that hold down pest species (for example, timing of cuttings and irrigations and the use of trap crops and rotations). Insecticides are used only when a primary pest species threatens to reach damaging populations in spite of other measures. When possible, selective materials are chosen, and these are applied at times least harmful to beneficial species.

Rational pest management usually requires more knowledge of insect species and crop ecology than the average farmer possesses and more time to monitor populations than he can devote. The use of pest management specialists answerable to both the farmers and state or federal entomologists is usually necessary. Their services are usually paid for by organizations of farmers, grouped along regional or commodity lines. In time it may become necessary for such services to be paid for from public funds and for a tightening of regulations to ensure proper functioning of the programs.

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As an ecologist and evolutionary biologist, I probably tend to view environmental problems over a longer time span than others. The use of pesticides is such a case. Many are concerned only with the immediate effects of pesticide application. However, if we are really interested in maintaining a quality environment through time, we should be critically examining the long-term effects of pesticides on the survival of plant and animal species and upon the world ecosystems.

Some organisms are capable of adapting to changes in their environment, particularly if the change is a gradual one. Such organisms as mosquitoes, houseflies and scale insects have shown an amazing ability to develop a genetic immunity to many pesticides.

A major problem as I view it is that we are literally dumping 400 to 500 new chemical compounds (some of which are pesticides) into the environment each year. These are compounds which have been synthesized in the laboratory and to which life has never previously been exposed. Most of these chemicals have been released into our atmosphere, water and soil within the last 25 years. We are therefore asking organisms, including man, to evolutionarily adapt to a very sudden environmental change.

Organisms with the appropriate genetic equipment, high mutation rates and short generation times can more readily adapt to such sudden changes. We therefore frequently end up developing super pests from the very species which we are attempting to control.

But if we must control pests, how can we accomplish this task with a minimum of environmental disturbance? Most ecologists feel that we must employ an “integrated control” program of pest management. Integrated control has as its goal the maintenance of potential pest populations below the level at which they cause serious health hazards or economic damage. It does not attempt to exterminate pests—a goal which incidentally has never been accomplished by chemical control programs.

In integrated control a crop may be protected by practices such as planting it in mixed stands with other crops, destroying pest reservoirs adjacent to the fields, introducing and encouraging predators and parasites, breeding more resistant crop strains, and using nonpersistent pesticides. Insect development may be disrupted by the use of hormonal pesticides. These and other practices may be combined to achieve both a high level of desirable control and a minimum of damage to the world ecosystems.

Integrated control temporarily may be more expensive than traditional chemical control programs. Because of our exploding world human population, we unfortunately may be unable to afford even the low level losses of crops inherent in integrated pest control programs. The world’s human population now numbers 3.6 billion and is expected to double in 35 years. Two-thirds of the world’s present inhabitants are either undernourished or malnourished. What will be their nutritional state with twice as many people to feed around the world? Widespread famines are sure to result in the near future if an immediate reduction in births to approximately two children per family does not occur.

Because of this ever-increasing human population, we are forced into taking ecological risks unnecessary in a smaller population. We employ chemical control programs which may result in ecological disaster in the future because they have an immediate short-term benefit. We must quickly switch to an ecologically sound integrated control program of pest management and this will be possible only with a stable human population.

The life span of the sperm whale is estimated at 75 years. The female does not reproduce until the 9th or 10th year, and she usually produces only one calf every four years.

Field observers report that the black vulture, turkey vulture and California condor are being crowded out by civilization, with the latter bordering on extinction.

Skipjack tuna forage from 30 to 60 miles out to sea in a single night, returning at dawn to their coastal site of departure.

Polar bears are known to travel from 30 to 50 miles a day on an ice pack which may also be moving at approximately the same rate.

The brown creeper is a sparrow-like bird which scurries up the trunk of a tree more like a mouse than a bird.

Wild turkeys usually have only one brood a season, but it can number up to 25 poults.

The sabre-toothed Pyara, a South American exotic game fish weighs up to 60 pounds.
The need for age determination as an aid in the management of big game populations has long been recognized (McLean, 1936).

Age classes for deer and other ungulates are most commonly determined from dentition characteristics. Difficulty, however, is sometimes encountered in opening frozen jaws or jaws from animals in rigor mortis.

A simple jaw opening device was made for opening deer jaws to adequately expose the teeth and aid in determining the animal's age. This tool was used in a management study on a herd of Rocky Mountain Mule Deer (Odocoileus h. hemionus). This device increased the efficiency of age taking deer which were brought to the checking station near Coalville, Utah, during 1964 and 1965. It may be equally as effective in examining the teeth of other big game animals.

The device is constructed from a 22-inch length of 1/2-inch steel rod bent to the specifications illustrated in figure 1. The flattened end of the jaw opening tool is inserted into the diastema of the deer and rotated to force the jaw open (figure 2).

The flattened end of the jaw opening tool can be driven into the mouth with a hammer when the heads are frozen.

Some of the most obvious advantages of this jaw opener are: (1) an experienced biologist can look through the center of the spreader and age the deer without slitting the cheek, and (2) it is small, light and usually can be operated with one hand.

Figure 1. Close-up photo showing the dimensions of a jaw opening device for deer and other big game animals.

Figure 2. The device in use is inserted into the mouth of a dead mule deer and rotated to force open the jaws for examination.
A total of 232 Rocky Mountain Mule Deer (Odocoileus h. hemionus) were trapped with modified Clover single-gate deer traps during the years 1964 to 1965 on the Coalville Deer Herd Unit 19 in northeastern Utah. Several modifications of the trap described earlier by Clover (1956), were found advantageous in terms of trapping success and operational efficiency. Problems encountered in Utah with the originally described deer trap were: (1) ice and snow froze on the rat-trap-trigging device rendered it inoperable, and (2) rabbits chewed both entrance and exit holes through the net to eat the alfalfa bait.

Modifications included: (1) completely eliminating the rat-trap-trigging device and substituting a nylon “kick” string trigger. By placing the alfalfa bait at the far end of the trap, the deer tripped the sliding gate while attempting to reach the bait. (2) A bar was added 5 inches above the trap base and the side netting tied to it. This created entrance and exit openings for rabbits on both sides, and deterred them from chewing holes in the net (figure 1).

Other modifications included: (1) the wood block deadmen and wire top braces were replaced with eight-foot ropes tied from each corner to a lateral center stake; and (2) deer, when caught inside the trap, were “bull-dogged” by the operator, or the trap was collapsed on them for handling. This eliminated the use of catch net. Both antlers of bucks were securely tied to the trap frame before the operator entered the trap.

**Figure 1.** Clover deer trap modifications: one-half-inch diameter metal loops; (2) anchor ropes; (3) nylon trigger string; and 5-inch-high opening to permit entrance or exit of rabbits.

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**DEER TRAP MODIFIED**

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