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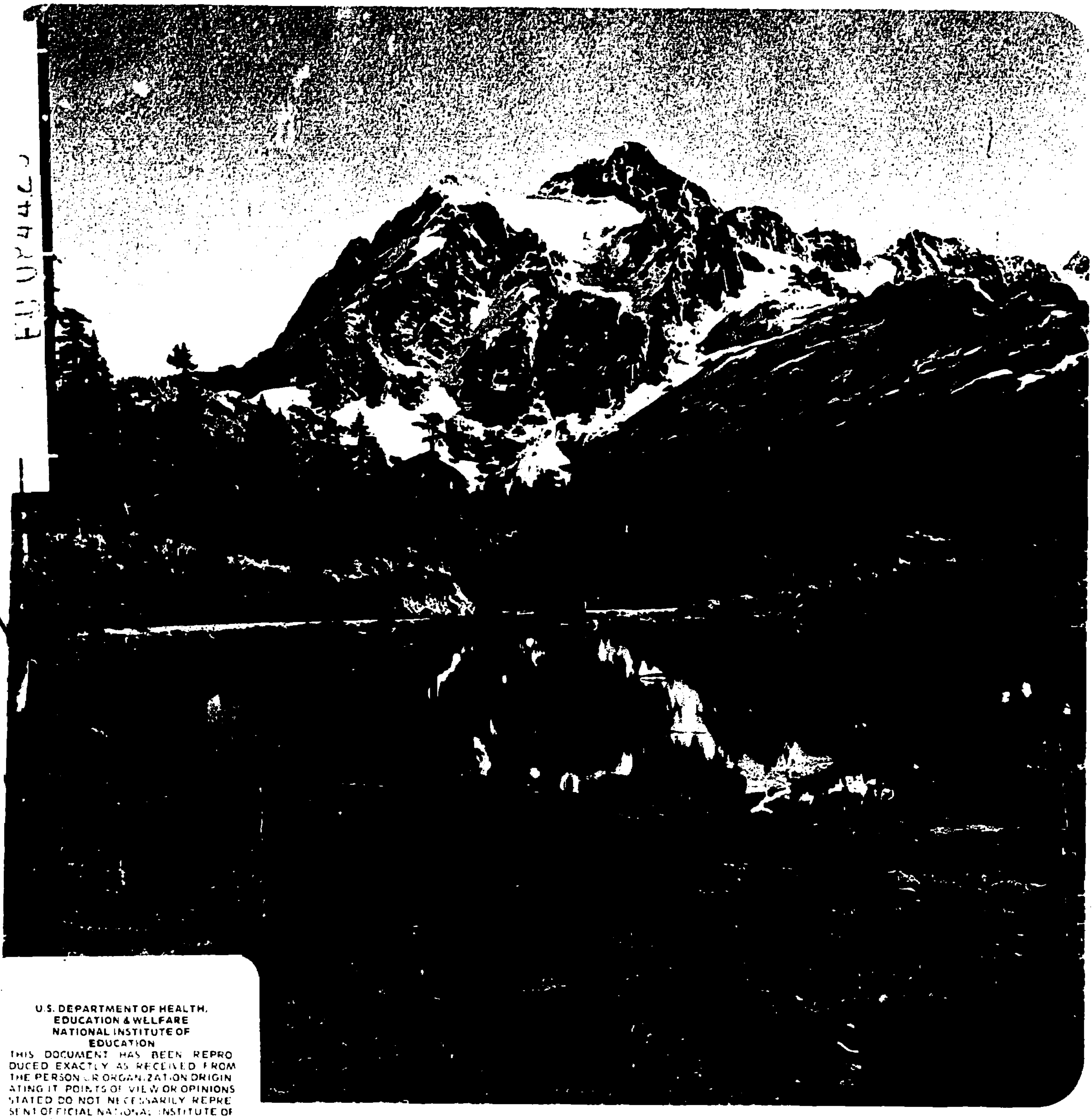
ABSTRACT

The document is designed to be used as a resource in teaching vocational agriculture high school students about the environment. Agricultural chemicals are the major focus, with some attention to radiation. The importance of safety in agricultural chemical use is stressed, with descriptions of the pesticide label; protective clothing; respiratory devices; correct application, transporting, handling, and disposal of chemicals; and health hazards. Agricultural chemicals are described by type: insecticides, fungicides and bactericides, herbicides, nematicides, rodenticides, and mammalian biocides. Legislation and regulation of agricultural chemicals are discussed. Tolerances--their establishment and enforcement--are covered. Alternatives to agricultural chemicals are treated. The section on radiation deals with sources and effects of radiation. A 6-page glossary and a 23-item bibliography are appended. (MS)



Ag Ed Environmental Education Series

AGRICULTURAL CHEMICALS AND RADIATION

WASHINGTON STATE UNIVERSITY IN COOPERATION WITH THE COORDINATING COUNCIL FOR OCCUPATIONAL EDUCATION.

73–3B

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- Air
- Agricultural Chemicals and Radiation
- Animals
- Land Use
- Noise
- Plants
- Understanding the Environment
- Water

AGRICULTURAL CHEMICALS AND RADIATION

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FOREWORD

This publication is the product of a project carried on by the Coordinating Council for Occupational Education and the Department of Education, Washington State University.

The project grew out of a recognition of the need to include as a part of the high school vocational agriculture curriculum information dealing with the environment, particularly as it relates to agriculture. The project was preceded by a period of growing concern that a body of factual information and teacher resources needed to be developed in this area.

E. M. Webb, associate professor of agricultural education emeritus, first suggested that steps be taken to make available to teachers of agriculture and their students factual information on the environment and agriculture. It was through the efforts of Jay Wood, program director, agricultural education, Olympia, that a project was prepared and approved beginning in September 1970.

Valuable assistance was given the project by many persons from the following agencies: Washington State University, University of Washington, Western Washington State College, Soil Conservation Service, United States Department of Agriculture, United States Department of the Interior, Washington Parks and Recreation Department, Washington Department of Ecology, Washington Department of Natural Resources, Washington Department of Agriculture, Washington Department of Fisheries, Washington Water Pollution Control Commission, Environmental Protection Agency, and Washington Department of Game. Many other agencies provided information for the project.

Three publications were extremely useful in preparing this unit. They were *Environmental Quality: The First Annual Report of the Council on Environmental Quality*, *Environmental Quality: The Second Annual Report of the Council on Environmental Quality*, and *Washington Pest Control Handbook*. Information from these publications was used as a basis for much of this unit.

Grateful acknowledgment is hereby made to the following groups of people: Dr. C. O. Loreen and Dr. Keith E. Fiscus, both teacher-educators and state supervisors in agricultural education, and Mr. Jay M. Wood, program director, agricultural education, who gave able assistance to this endeavor. Mr. John Babich, Mr. Donald Bayes, Mr. Marvin Evers, Mr. Carl Jensen, Mr. Ronald Miller, Mr. John Musser, Mr. Walter Pierson, and Mr. Douglas Scoville, teachers of agricultural education in Washington high schools, reviewed the unit, developed teaching materials to be used with the unit, and taught the unit to their students. Many other teachers also made valuable contributions to the project.

The following subject-matter specialists reviewed the unit or parts of the unit: Dr. Robert Harwood, chairman, Department of Entomology, Washington State University; Dr. Otis Maloy, extension plant pathologist, Washington State University; Dr. Richard Maxwell, assistant agricultural scientist, Department of Agricultural Chemistry, Washington State University; Dr. Roland Schirman, collaborator, USDA, agronomy, Washington State University; and Dr. Horace Telford, professor of entomology, Washington State University.

This unit is one of eight being produced under the project. The other seven include: *Understanding the Environment, Water, Noise, Land Use, Animals, Plants,* and *Air.*

July 1972 Rodney W. Tulloch

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INTRODUCTION

The use of agricultural chemicals as we know them today has been a rather recent development. Quite a few of the chemicals that have now become household terms had not been discovered 30 or 40 years ago.

Most of the great changes through history have taken place rather slowly. Even after the invention of the tractor, it was many years before it was fully accepted. It has often taken 25 years of debate to formulate policy on which to base change. It has often been another 25 or 50 years before the change is accepted by the general public. It is, therefore, somewhat startling that both farmers and consumers have so readily accepted a multitude of new agricultural chemicals. This is especially startling when we consider that farmers have often been conservative in their approach to change, especially when it was to affect their land, and consumers have been quite selective in their food buying. It is likely that several factors contributed to the rapid acceptance of changes in agricultural chemicals.

World War II brought about great pressure to both increase yields and produce the higher yields more efficiently. In meeting these demands, new chemicals were discovered and developed that brought about marvelous changes in agriculture. Some of the people who had suffered through the Depression had a more receptive attitude toward change, particularly when the change would help prevent people from going hungry. Many chemicals were produced commercially shortly after their discovery or development simply because there were great demands for them. Some of the improved methods, including use of agricultural chemicals, also pointed the way to more profit, which few people were against.

Many of these changes took place with a minimal amount of questioning. This is not to say that procedures of testing, research, and development have not been required before use of most types of agricultural chemicals. A more thorough discussion of the steps and costs involved in developing new agricultural chemicals will be covered later in this unit.

The insecticidal properties of DDT were discovered in 1939. DDT was used some in the field mostly by the military in the early 1940s. It became commercially available to the public in this and other countries about 1945. The discovery, development, and release of 2,4-D was very similar to that of DDT. This was the start of the release of a great number of new materials and the beginning of a major new industry.

By the end of the fifties and the beginning of the sixties, people were becoming aware of some problems involved with agricultural chemicals. The producers of agricultural chemicals had found a growing resistance toward agricultural chemicals and a tightening of the controls on their registration.

It was in 1962 that Rachel Carson's *Silent Spring* was published. This book confirmed the suspicions that some had and raised questions in the minds of others. Some of the material included in this book was inaccurate, and other parts of the book were overdramatized. Because of this, it is this author's opinion that many of us in agriculture entirely disregarded the book. This, in hindsight, would seem to be unfortunate since the book did raise questions that needed answers then and still do. Good research on the long-term effects of agricultural chemicals was and is very necessary.

An extensive two-part report titled *Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health* was completed and sent to the Secretary of Health, Education, and Welfare on December 5, 1969. The chairman of this commission was Dr. Emil M. Mrak, chancellor emeritus, University of California at Davis. The report is often referred to as the Mrak Report. In the report, the following fourteen recommendations are given:

1) Initiate closer cooperation among the Departments of Health, Education, and Welfare; Agriculture; and Interior on pesticide problems through establishment of a new interagency agreement.
2) Improve cooperation among the various elements of the Department of Health, Education, and Welfare that are concerned with the effects of pest control and pesticides.
3) Eliminate within 2 years all use of DDT and DDD in the United States, excepting those uses essential to the preservation of human health or welfare and approved unanimously by the Secretaries of the Departments of Health, Education, and Welfare; Agriculture; and Interior.
4) Restrict the use of certain persistent pesticides in the United States to specific essential uses that create no known hazard to human health or to the quality of the environment and are unanimously approved by the Secretaries of the Departments of Health, Education, and Welfare; Agriculture; and Interior.
5) Minimize human exposure to those pesticides considered to present a potential health hazard to man.
6) Create a pesticide advisory committee in the Department of Health, Education, and Welfare to evaluate information on the hazards of pesticides to human health and environmental quality and to advise the Secretary on related matters.
7) Develop suitable standards for pesticide content in food, water, and air and other aspects of environmental quality that: (a) protect the public from undue hazards, and (b) recognize the need for optimal human nutrition and food supply.
8) Seek modification of the Delaney clause to permit the Secretary of the Department of Health, Education, and Welfare to determine when evidence of carcinogenesis justifies restrictive action concerning food containing analytically detectable traces of chemicals (fig. 1).

   The Delaney clause is contained in the Federal Food, Drug, and Cosmetic Act, as amended, section 409(c)(3)(A). The effect of this clause is to require the removal from interstate commerce of any food that contains analytically detectable amounts of a food additive shown to be capable of inducing cancer in experimental animals. This would include several agricultural chemicals of which DDT is one. Since there is already considerable DDT in the environment, even if none were ever used again, there would be residues around for some time to come. When this law was passed, our measurement devices were not as good as they are now and parts per billion could not be measured. It would seem logical that, where it takes large amounts of a material to cause any problem, then at least very low levels of pesticide residues could be tolerated. If this clause was fully enforced, it would outlaw most foods of animal origin. Such foods would include meat, dairy products, eggs, and fish.
9) Establish a Department of Health, Education, and Welfare clearinghouse for pesticide information, and develop pesticide protection teams.
10) Increase Federal support of research on all methods of pest control, the effects of pesticides on human health and on the ecosystems, and on improved techniques for prediction of human effects.
11) Provide incentives to industry to encourage the development of more specific pest control chemicals.
12) Review and consider the adequacy of various legislation and regulations. (This recommendation has been shortened from the version in the report.)

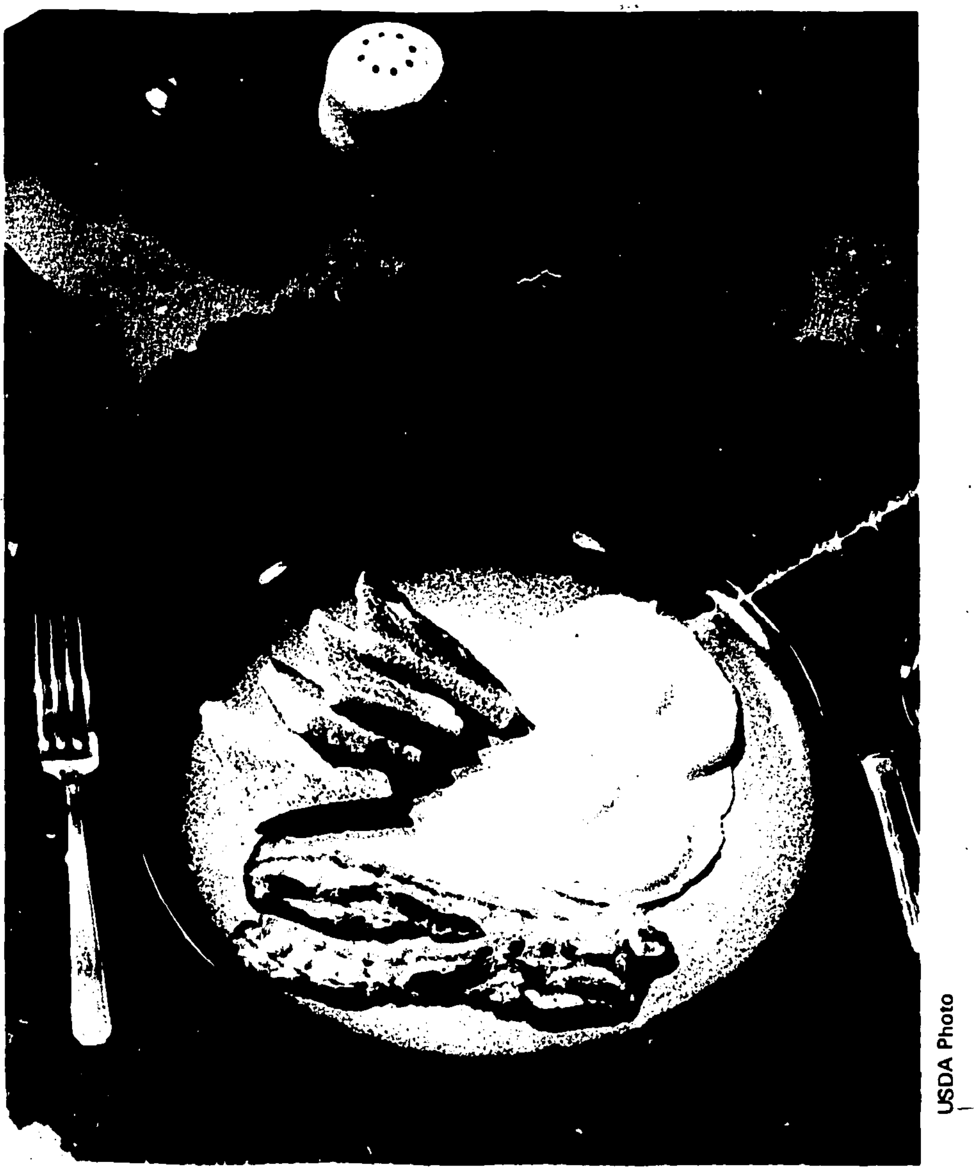

Fig. 1—If the Delaney clause were fully enforced, the meat, eggs, and butter would not be in this picture.

13) Develop, in consultation with the Council of State Governments, model regulations for the collection and disposal of unused pesticides, used containers, and other pesticide-contaminated materials.
14) Increase participation in international cooperative efforts to promote safe and effective use of pesticides.

Due to this report and the interested concern of many other people, changes have been and are being made in relation to agricultural chemical registration and use. Some of the changes that have taken place or are being considered can be seen under the section "Alternatives to Agricultural Chemicals."

The debate over the use and misuse of agricultural chemicals will probably continue into the foreseeable future. People become very emotional over this issue because they feel it may have serious consequences to their health. Agricultural producers, on the other hand, become quite emotional because serious restrictions of the use of agricultural chemicals could have disastrous results on their production. Still another argument states that, with the present world population and the number of starving people, restricting or banning the use of large numbers of present agricultural chemicals could cause unprecedented starvation. Once the importance of these issues to various groups is seen, there is little wonder that there is great debate over the use of agricultural chemicals.

USING AGRICULTURAL CHEMICALS SAFELY

A great amount of research goes into each chemical before it is released. After all the research is done, much of the safety during use of agricultural chemicals is up to the individual applicator. Licensing of people who give advice about, apply, or sell agricultural chemicals is required in many States.

Suggestions for Safe Use of Chemicals

Know the pest, and apply chemicals only when needed. Ask the advice of an authority. Use a chemical recommended for the problem, and know the hazards involved. READ THE LABEL. Check with your physician and tell him about chemicals you will be using, especially organophosphorus pesticides and other highly toxic materials. Make sure that he is familiar with signs and symptoms of chemical poisoning and with antidotes (and has them on hand). Have poison information center and physician's phone numbers posted by your phone. Make sure that all persons around chemicals and equipment understand their safe use. Keep equipment in good shape and calibrated. Wear proper and clean equipment and clothing. Make sure chemicals are received and stored correctly.

Warn humans and remove livestock and pets from areas that may be exposed. This may be a much greater area than that to be treated. Protect bees and other nontarget insects as much as possible. Cover all food, feed, and water and their containers.

RE-READ THE LABEL. Make sure that intervals between applications and between application and harvest, slaughter, milking, or planting comply with those given on the label.

The Pesticide Label

Research costing millions of dollars is usually spent before a pesticide is registered and offered for sale. The information on the label is based on this extensive and costly research. The importance of reading and following the information on the label can hardly be overemphasized. The time spent in reading the label may be the most important time spent in pest control. If read, understood, and followed, the instructions can save money and avoid costly or deadly accidents.

By law, the label must contain the brand name, intended use of the product, and active and inert ingredients. It must give directions for use, including pests to be controlled; crops,

Fig. 2—This symbol was developed by USDA to encourage safe and effective use of pesticides.

animals, or sites to be treated; dosage or rate; and time and method of application. It must, depending on its toxicity, carry warnings that protect the user, the consumer of treated foods, beneficial plants, and animals plus a warning to KEEP OUT OF REACH OF CHILDREN. The label must also show the net contents, name and address of the manufacturer or registrant, and Environmental Protection Agency (EPA) registration number.

Before you purchase a chemical, you should read the label to determine that it is the correct chemical for the use you intend to make of it and that the material is not too toxic or hazardous for the use or application method. The USDA has developed a symbol to remind people to read the label (fig. 2). Also determine the amount or concentration of active ingredients. The inert ingredients or carriers may also affect the use of the material.

The label also provides information that should be read before mixing, applying, or disposing of materials or containers and for their proper and safe storage.

Protective Clothing and Respiratory Devices

The use of protective clothing and other safety devices offers some protection against skin contact and/or inhalation of certain pesticides by the operator, but it does not eliminate the necessity for other essential precautions.

Coveralls, rainsuits, head and neck coverings, boots, gloves, goggles, and respiratory devices are designed to protect the person who is handling or applying pesticides from direct contact. The concentrated formulation is the most serious threat in this respect. Therefore, be especially careful when removing concentrated pesticides from their containers, when mixing, and when filling application equipment. However, continuous exposure to dilute formulations of some pesticides can be equally as dangerous, so proper precautions should be followed at all times.

Check the label of the pesticide container! If it calls for the use of certain pieces of protective equipment or garments, use them.

Two kinds of respiratory protective devices are in general use: chemical cartridge respirators and gas masks. Most respirators are designed as half-face masks that cover the nose and mouth but do not protect the eyes. They have one or two cartridges attached to the facepiece by a clamp or secured in a holder. The respirator facepieces are equipped with one-way valves that allow the inhaled air to pass through the cartridges but prevent the exhaled moist breath from passing through the cartridges. The exhaled air goes out another one-way valve.

Gas masks usually cover the entire face. Their facepieces are made to hold a canister directly or to connect to the canister with a flexible hose. The hose-type canister is carried on the chest or back by means of straps. Gas masks have larger filtering capacity than respirators.

Respirator cartridges usually contain an absorbing material such as activated charcoal. Respirators also have efficient filters that remove dust and spray particles and thus prolong the life of the absorbing material. Gas-mask canisters always contain more absorbing material and filters with longer life than do the respirator cartridges.

The life of chemical-absorbing cartridges or canisters will be affected by humidity, temperature, and volume of breathing. High humidity shortens the life of cartridges and canisters in use and in storage. Mist, sprays of water, and rain reduce the effective period of the units. Cartridges and canisters in storage will gradually lose their effectiveness because of the exchange of air within the unit due to changes in temperature and atmospheric pressure.

Because of the differences in their protective capacities, gas masks, not respirators, must be worn when pesticides are formulated in close or inadequately ventilated spaces. We recommend that gas masks be worn in greenhouses and in buildings when highly toxic materials are applied because they filter the air more thoroughly than respirators.

It is necessary that respirators be used in handling pesticides during the loading of distribution equipment, when containers are being disposed of, and whenever operators are exposed to obvious amounts of dusts or mists of the more dangerous pesticides. Field operators who may be exposed continuously during the day or for successive days to small amounts of toxic pesticides—even those not readily detectable—should faithfully use respirators as a precaution.

Respirators will give airplane pilots adequate protection against most insecticides during normal dusting or spraying operations, but care should be taken to select and wear goggles that provide a tight seal with the respirator around the nosepiece. Pilots who are exposed to high concentrations of the more toxic pesticides must wear gas masks.

When respirators are used, the following practices are necessary:

- Change filters twice a day or more often if breathing becomes difficult.
- Change cartridges after 8 hours of actual use or more often if any odor of the pesticides is detected.
- Remove filters and cartridges and wash the facepiece with soap and water after use. After washing, rinse the facepiece to remove all traces of soap. Dry it with a clean cloth that is not contaminated with the pesticide. Place the facepiece in a well-ventilated area to complete drying.
- Store the respirator, filters, and cartridges in a clean, dry place—preferably in a tightly closed paper or plastic bag.

The respirator should be fitted properly on the face, not too high on the nose, with the narrow part over the bridge of the nose, and the chincup contacting the underside of the chin. Adjust headbands just tight enough to ensure a good seal. Manufacturers can supply a special facepiece if the standard one does not fit.

The use of a respiratory protective device does not eliminate the need for other precautions in handling toxic pesticides. If an operator shows any sign of dizziness or nausea, he should be removed immediately from the area and placed in the care of a physician before he returns to work.

Importance of Correct Application

It has become more common in recent years to make claims for damages by agricultural chemicals. Such damages may be asked for nonperformance or for alleged injury to crops being treated or adjacent crops.

In general, the courts have held that the grower or employer as well as the applicator, even if he is a private contractor, are both responsible for drift damage. Applicators in the State of Washington are required by State Department of Agriculture regulations to show evidence of financial responsibility pertaining to potential drift losses before a license can be issued.

Claims alleging injury to a treated crop, or nonperformance of the pesticide, fall under either the theory of negligence, breach of implied warranty, or expressed warranty. If the applicator did not sell the pesticide that was applied, the dealer, distributor, and manufacturer will frequently be interpleaded (go to court against each other) to determine what is most at fault, the application or the product itself, in order to determine appropriate liabilities.

In cases involving crops being treated when the alleged injury is not substantial, the grower must show how much injury was caused by the pesticide and how much was occasioned by any and all other adverse conditions (e.g., weather, disease, etc.). If it can be proven that the damage was total or substantial, then segregation of other causes is not usually required.

Keep in mind that insurance coverage provided by aerial application policies specifically excludes coverage for crops being treated. This is noted in the Washington State regulations pertaining to financial responsibility.

When a pesticide is applied to a field other than that intended, either through error of the applicator or the grower, a very serious situation develops since the applicator may well be found guilty of trespass. If the field contains the same crop as the one intended to be treated, frequently no great harm will occur unless the pesticide results in overdosage. On the other hand, if the field contains a crop different from that intended for treatment, damages may be substantial either from overtolerance of pesticide residue resulting in condemnation of the crop or from phytotoxicity. In cases of this type, the applicator will normally be held on the basis of trespass, and defense will be most difficult.

With the current concern about pollution, cases involving alleged noise damage or injury may be presented against an applicator. In general, the courts have held that the pilot and/or his employer are liable if the complaining party can show direct loss of property, such as poultry, mink, etc., resulting from fright occasioned by the noise of aircraft or ground equipment operated in a careless and negligent manner. This is particularly important with aerial applications when pullups are necessary over adjoining property. In such cases, the complaining party will normally allege an unlawful flight over his property without his permission. Successful defense of such actions has been achieved where it has been demonstrated that the noise in question was not the proximate cause of the alleged injury to the plaintiff's animals or that no such injury occurred.

Claims involving the application of the "attractive nuisance" doctrine result primarily where children have been attracted to moving ground equipment or to parked aircraft and have fallen or injured themselves. In one case, a young boy entered a cotton field that had been defoliated by an aerial application and was burned after setting fire to the desiccated cotton leaves. A suit was filed naming the applicator, the owner of the cotton crop, and the supplier of the chemical, on the theory that an attractive nuisance had been created and that

Fig. 3—Highly toxic pesticides should be applied with extreme care to avoid drift injury to innocent parties.

substantial injury had resulted to the young boy as a result of the fire, which he himself started. The moral is do not leave ground equipment with exposed drive belts, drive wheels, gears, or any moving parts unattended in areas where children have access. Unattended aircraft should not be parked in an area where temptation to investigate may result in injury to children.

Extreme care must be taken when using organophosphate insecticides to avoid drift injury to innocent parties located outside the field being treated (fig. 3). No grower or applicator can assume that those located across the street or who are passing by will not be injured. Every precaution should be taken to avoid application of highly toxic pesticides in situations that could give rise to alleged bodily injury.

Even sealed containers are sometimes found to accidently contain a mixture of different pesticides. Applying such materials could result in serious damage. An applicator needs to develop an ability to recognize such errors.

An applicator or grower can be liable for death of bees if drift occurs. However, if it can be shown that the bees trespassed into the treated field, then the applicator is not held responsible.

An applicator may also be held responsible for ineffective application of pesticides. In order for application of a pesticide to be effective, the pesticide must contact or pass into the pest organisms. The pesticide may be applied to "get at" a pest by a number of routes. Any one material may be applied by a number of routes; however, some generalizations can be made about fungicides, agricultural disinfectants, and bactericides. Basically, these are applied to protect with the aim of achieving a complete coverage over the surface to be protected before disease conditions are expected. A fungal spore or bacterial cell that arrives on the protected (treated) surface is prevented from growing (or infecting the organism being protected). Fungicides will be applied at certain times of the year in a certain locality to a certain crop, based on knowledge of local disease conditions and expectations.

With insecticides and rodenticides, timing is critical—based on knowledge of life history, habits, and behavior of the organisms. Coverage and protectant action (before infestation has occurred) *may* be less important (depending on circumstances). For example, the pest organisms may move about and come into contact with the pesticide or pesticide bait.

Equipment is important in the correct application of agricultural chemicals. Positive agitation in the tank is needed to ensure thorough mixing of the pesticide solution. This is particularly important for wettable powders. Pumps need to be able to supply enough flow and pressure to do the job. Spray booms or air blast sprayers must be adjusted to cover the area as required but should also minimize risk of drift.

Compatibility of Agricultural Chemicals

To increase the effectiveness of a chemical, a manufacturer may want to increase the activity of his chemical against specific pests. He does this by adding a chemical referred to as a synergist, which is not an active pesticide but which increases the effectiveness of the pesticide. Synergists usually increase the toxicity of the pesticide so that a smaller amount is needed to bring about the desired effect. This may reduce the cost of the application and also reduce the hazard because less of the active material is used.

Applicators sometimes combine two or more active pesticides to kill a pest that has not been effectively controlled by either chemical alone. Many combinations are quite effective; but, in most cases, it is not known if the improved control is a result of a synergistic action or an additive effect of the several chemicals on different segments of the pest population.

Frequently, several types of pests need to be controlled at the same time; e.g., insects, diseases, mites. Generally, it is more economical to combine the pesticides needed and make a single application—in this case, an insecticide, a fungicide, and an acaricide. However, the compatibility of the various chemicals must be known before the materials are combined.

Some combinations of chemicals result in mixtures that produce the opposite effect of synergism, known as antagonism. Antagonism or incompatibility may result in chemical reactions that cause the formation of new compounds or a separation of pesticide from the water or other carrying agent. If one of these reactions occurs, one of the following may result:

- Effectiveness of one or both compounds may be reduced.
- Precipitation may occur and clog screen and nozzles of application equipment.
- Various types of plant injury (phytotoxicity) may occur; e.g., russeting of fruits or vegetables, stunting of plants, and reduction of seed germination and production.

- Excessive residues may result.
- There may be excessive runoff.

Another less familiar but extremely important undesirable effect of combining certain pesticides is potentiation. Some of the organophosphate pesticides potentiate or activate each other as far as animal toxicity is concerned. In some cases, the combination increases the toxicity of a compound from one that is normally of very low toxicity to one that is highly toxic to man and other animals.

Phytotoxicity, excessive residue, or poisoning of livestock also can occur when one chemical is applied several days after the application of a different chemical. Check the pesticide label carefully for such warnings.

When a combination of chemicals is to be made, refer to the compatibility charts that are available through your pesticide salesman or from one of the fruitgrower journals.

Because of the risks involved, combinations of pesticides and/or other agricultural chemicals should not be used unless the specific combination has been proven to be effective, tested for side effects, and accepted for registration by the State Department of Agriculture or the EPA.

Transporting and Handling Chemicals

The hazardous nature of many pesticides requires strict regulation for their transportation. The Federal Department of Transportation is the major regulatory agency involved in enforcing hazardous materials laws. The Code of Federal Regulations, Title 49: Transportation, is the major document covering all aspects of the field of transportation regarding pesticides and other hazardous materials. Persons engaged in the transportation of pesticides, either intrastate or interstate, should be familiar with this code.

The classification of poisons has recently been revised to be in accordance with the various types of health hazards associated with pesticides. Hazards now considered are: systemic, i.e., inhalation, ingestion, or absorption through the skin; contact, i.e., causing destruction of living tissues by thermal or chemical action; or irritant, i.e., causing local irritating effects on eyes, nose, or throat.

The new classification also carries with it a new testing procedure for toxicity that must be performed on each formulation of pesticide sold. Generally, class A poison is any material rated at an LD_{50}* of less than 5 milligrams per kilogram (mg/kg), LC_{50}** of less than 75 ppm in air, or LC_{50} of less than 100 mg/kg in contact with skin for less than 1 hour. A class B poison is any material with an LD_{50} of less than 50 mg/kg orally, an LC_{50} of less than 200 ppm in air, and an LC_{50} of less than 200 mg/kg in contact with skin for less than 1 hour.

Containers must meet certain specifications and be clearly labeled. Trucks carrying hazardous materials must be marked with placards (signs).

A great number of other regulations cover technical personnel, packaging and shipping personnel, loading and unloading, and driving and parking rules.

All incidents involving hazardous materials in transportation must be reported to the U.S. Department of Transportation, and major incidents must be reported to the Washington State Department of Social and Health Services and the Department of Agriculture.

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*LD = lethal dosage
**LC = lethal concentration

Disposal of Waste Chemicals and Containers

The improper disposal of pesticide wastes and containers over the past two decades has resulted in a number of incidents of animal poisonings and environmental contamination.

Pesticide waste may range in type from waste left after a pesticide fire or spillage to spray material left after an application. The type of pesticide container may vary from hard-to-dispose-of 55-gallon drums, to aerosol cans, to paper bags still containing pesticides. Each type of pesticide waste requires a special disposal decision.

Pesticide wastes, particularly "empty" pesticide containers, may be scavenged from an unsupervised dump for use in a nonprescribed manner resulting in poisoning as exemplified by the mercury poisoning episode in New Mexico resulting from the use of waste, mercury-treated, seed grain. In this instance, members of a family were poisoned from eating pork from a hog that was fed mercury-treated grain taken from a disposal site. Also, the "empty" pesticide container is never really empty as several ounces of pesticides are generally found in discarded containers. Another important fact is that concentrations of the active ingredient of liquid formulations may increase in toxicity through evaporation of solvents. From this it is evident that the pesticide container is potentially one of the major sources for pesticide-induced illness in the community.

Pesticides and pesticide containers should be kept in a separate building, room, or enclosure used exclusively for that purpose. Buildings or rooms used for such storage should be dry, constructed with nonabsorbent floors, well ventilated, and under lock and key. Outside storage areas should be fenced to protect children and animals and to discourage pilferage. Also, outside areas should be sloped into ditches or drains leading into a catch basin.

CAUTION: Do not store weedkillers, herbicides, or defoliants in the same room with insecticides. Volatile materials, such as 2,4-D and its derivatives, can contaminate other pesticides. Chlorate salts can cause fires or explosions.

Remove only the amount of pesticides needed for one day's operation, and be sure to return "empty" cont· iners—and any unused pesticides—to the storage area at the end of each day.

Special holding areas for empty pesticide containers should be constructed by applicators or pesticide users for temporary storage until proper disposal can be arranged. A cyclone-type fence at least 6 feet high with a locked gate and adequately posted with warning signs is recommended by the State Department of Agriculture.

Aerial applicators and pest control operators may wish to construct a concrete pad for cleaning application equipment. The pad should be equipped with a proper drain and sump and an open drain field under gravel. Care should be taken in constructing the sump and drain field. The system should be enclosed without an outlet as the applicator may need to pump out the sump and remove the material to a disposal site. The drain field may need to be replenished with clean gravel at various periods.

Persons needing to dispose of pesticide containers and wastes may call their local health department for information regarding disposal of such materials. Each local health department, in cooperation with the State Department of Ecology, has designated pesticide disposal sites throughout the State. These sites have been chosen because of their safe disposal characteristics rather than for convenience of location and arrangement. Also, a few sites will be privately owned, and payment for dumping will be expected. Cooperation and consideration is asked of the pesticide industry in promoting the proper use of these dump sites.

As mentioned earlier, "empty" pesticide containers are particularly hazardous since they are never completely empty. Two to three ounces of toxicant are often found in empty pesticide containers. This is not only hazardous but a waste of pesticides. You can largely decontaminate containers by simply rinsing them twice and emptying the washings back into the spray tank. This removes about 98% of the toxicant. In addition, the remaining material is diluted and starts to break down by hydrolysis.

When diluted with alkaline water, many pesticides will break down rapidly upon exposure to sunlight and bacterial action.

Metal containers should also be rendered unusable either by compacting or by spiking the top, bottom, and sides with a straight claw hammer.

Keep surplus pesticides in the original container if at all possible. Repackaging of pesticides from broken containers must meet the same standards as the original container if they are to be transported.

The homeowner should purchase only small amounts of pesticide as needed. Packaging for the home user is convenient, and small amounts of pesticides may be purchased for a particular spray application job.

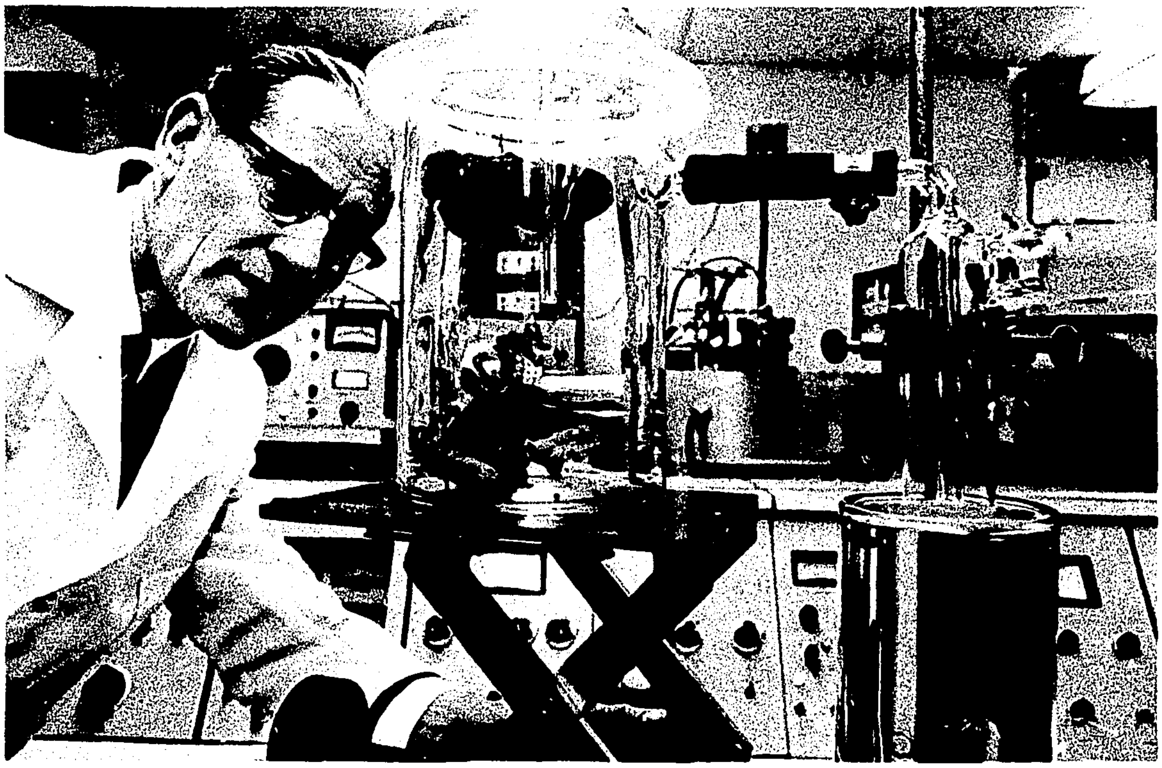
The homeowner, in areas with good sanitary service, especially a good sanitary landfill, may wrap the pesticide containers in newspaper, label the outside "pesticide," and deliver it personally to the garbage collector. The homeowner may also call his local health department for instructions on pesticide disposal if needed.

Health Hazards of Agricultural Chemicals

Users of pesticides should be concerned with the hazards associated with the exposure to the chemical and not exclusively the toxicity of the material itself. These two terms are not synonymous. *Toxicity* is the inherent capacity of a substance to produce injury or death. *Hazard* is a function of two primary variables, toxicity and exposure, and is the probability that injury will result from the use of a substance in a given formulation, quantity, or manner. Therefore, toxicity ratings should not depend exclusively on toxicity values as the only factor to be considered regarding the toxic effect of a chemical on humans or other animals. Some hazards do not involve toxicity to humans or other animals. For example, sulfur, oils, and numerous other chemicals are considered safe or relatively safe to animals, but they may pose considerable hazard to some plants (phytotoxicity).

Toxicology is directed toward the evaluation of safety, basing its conclusions on studies of chemical composition and reactivity, physical properties, degradative or metabolic transformations undergone by the materials involved, and biological effects of potentially injurious agents. Such biological effects are assessed by means of observations of alteration of structure, function, and response in living systems (fig. 4).

There are a great number of pesticides, and they vary widely physically, chemically, and biologically. They are used in many different ways, and new pesticides as well as new uses of pesticides are constantly being developed. The results when humans are exposed to them is often unpredictable. Human reaction to a pesticide may change depending on place, time, and other circumstances.



USDA Photo by M. Lemmon

Fig. 4—Trailblazing entomologist Edward F. Knipling with jar of moths used in research.

Agent and Environmental Variables

Some of the complexities of the pesticide problem arise from the fact that these are technical-grade materials often containing byproducts and other impurities whose nature and proportions may vary from one source to another, may vary (in countries where adequate control is not exercised) from one batch to another from the same manufacturer, and may change under conditions of storage. The accompanying impurities may themselves play an important part in the biological effects of a pesticide, for instance, in human sensitization to a product. Moreover, the impurities may interact with one another and with other compounds present in a pesticide formulation. This raises the question of the many formulating agents that are used and the effects of storage on the toxicity of the vehicles.

Changes in the compounds involved in the application of a pesticide also occur under the influence of environmental factors such as temperature, sunlight, plant metabolism, and degradation in the soil, depending on terrain, pH, humidity, and intensity of ultraviolet irradiation. Pesticides are spread through the environment in many ways. Together with food-chain magnification, the changes undergone by the pesticide in the course of translocation tend to complicate the picture further.

Limitations of Studies Under Experimental Conditions

No account of toxicological complexities would be complete without referring, however briefly, to the animals in which biological effects are studied. While some progress has been made in recent years in the provision of healthier and more uniform stocks of laboratory animals, variations in the response to a chemical will always continue to be manifest as a result of species, strain, sex, age, and individual differences in susceptibility.

One objective of toxicological investigation is to delineate at least some of these differences and to ascertain in the most sensitive animal species the maximum level of exposure that elicits no adverse effect. Using this level as a basis for extrapolation, an acceptable daily intake for man is arrived at by applying an arbitrary safety factor.

Some of the weaknesses of this approach are readily apparent. Practical considerations must always limit the number of species, strains, etc., of animals investigated. The criteria used and tests applied to ascertain that no adverse effect has occurred are often the best available, but methodology has not yet been developed specifically for this purpose to a degree permitting measured confidence that adverse effects have not been overlooked. Much more work is needed in this area, both in the direction of sensitive and specific methods of detecting changes and in an attempt to distinguish more clearly between those effects that represent physiological adaptation and those that constitute pathological change.

If the change is physiological adaptation to the pesticide, there is usually little problem. If, on the other hand, the change is a pathological change (change in tissue), very serious problems may result.

The considerations, limitations, and safeguards that enter into the use of human volunteers for research of this sort are now well recognized and widely accepted. Limited though such studies must necessarily be, both in duration and level of exposure, they do yield invaluable information, obtained under controlled conditions, that no other approach can provide.

Further Complexities in Man

Besides variations among individuals as to the level of pesticide exposure that they can withstand, several other factors are important. Occupation, the amount of physical protection used through wearing of clothing and masks, age, diet, race, socioeconomic status, home, and the drugs one is taking will all affect the amount of pesticides an individual absorbs. These factors may also affect his ability to cope with exposure to a pesticide.

Analytical Complexities

An appreciation of some of the more important analytical and interpretative problems peculiar to the organochlorines is essential for perspective.

A recently discovered source of error in analyses of DDT and related materials by gas chromatography is the presence of polybiphenyls (PCBs). Since 1929, polychlorinated biphenyl liquids, resins, or solids have been spread widely in our environment in oils, hydraulic fluids, adhesives, plastics, building materials, fuels, fire retardants, heat-transfer agents, electrical equipment, paper, and many other products. The presence of PCBs has caused serious analytical errors in the nonspecific gas chromatographic analysis of the chlorinated hydrocarbons. It is clearly necessary to confirm qualitatively the determination of DDT residues and not to be confused by gas chromatographic peaks that overlap DDT but represent totally different materials. Such false peaks have been reported in gas chromatograms from some wildlife samples, along with organochlorine pesticides. Cod liver oil from Norway gave rise to gas chromatographic peaks in the region expected for DDT, DDE, and TDE, but paper chromatography indicated the presence of halogenated compounds that were not known pesticides at all.

Complexities of Terminology

A large body of information has been published regarding the health consequences of human exposure to pesticides. Review of these publications reveals that the scientific terminology is often imprecise and nonuniform from one publication to another. Particularly troublesome and confusing are adjectives commonly used to qualify the terms "exposure" and "effect." Terms frequently used to describe exposure are "acute" and "chronic," "high level" and "low level," and "short term" and "long term." Among the terms that have been used to describe effects are "acute" and "chronic," "transient" and "permanent," and "immediate" and "delayed." While it is not within the scope of this unit to propose a standardized exposure/effect nomenclature, the absence of uniformity among authors in this respect must be emphasized.

The terms "acute toxicity" and "chronic toxicity" deserve comment. Acute toxicity usually implies overwhelming intoxication with obvious illness or death. Often only one pesticide is involved and the diagnosis is relatively clear cut. Chronic toxicity is, as a rule, more difficult to interpret and usually refers to illness resulting from long-term, relatively low-level exposure to pesticides. The data concerning intensity and duration of exposure are often unclear or incomplete.

Contributing to these interpretative pitfalls is the concept of the acute LD_{50}, which is the quantity of pesticide that, when given in a single dose, is lethal to 50% of the test group. The species, strain, age, and sex of the experimental animal, route of administration, concentration of test material, and vehicle in which active agent is administered must be specified. Even the most carefully established LD_{50} data cannot be applied to man except in a general fashion. Thus, while it is true that pesticides that are highly toxic to the experimental animal are usually quite poisonous to man, dose/response relationships are usually very different.

This is only one of the uncertainties involved in applying animal data to man. In recent years, a great deal of attention has been devoted to this question. The conclusion that emerges is that only studies in man can provide definitive answers to the questions posed by human exposure to pesticides and other chemicals. Results of experimental studies in animals are at best a guide, providing what are often valuable clues to the nature of the effects that should be looked for in human studies. The fact that every man, woman, and child in this Nation is exposed to pesticides in one form or another demands that answers be forthcoming that are known to be valid for man.

TYPES AND USES OF AGRICULTURAL CHEMICALS

Agricultural chemicals are simply chemicals that are used in agriculture. Such chemicals are used to control pests or protect crops, livestock, food, fiber, and other products from pests. They also protect or improve plants and animals and they erradicate or control diseases and weeds. Many of these chemicals are divided into groups according to their uses. These uses often have names that quite clearly identify what the chemical will be used for. These chemicals include insecticides, attractants, chemical sterilants, defoliants, desiccants, fumigants, fungicides, herbicides, nematocides, repellents, and rodenticides. A broader term that is used to cover chemicals for controlling or destroying a wide range of pests is "pesticide."

Some of the more important pesticides are herbicides, insecticides, and fungicides. The amount of herbicides being used has shown a dramatic increase in the past few years. Insecticides are also increasing in the quantities used, but not nearly so rapidly. At present, the United States produces from 50% to 75% of all pesticides manufactured in the world. As other countries improve their abilities to produce these chemicals, the percentage produced by the United States will probably decrease.

Insecticides

Insecticides are chemicals used for controlling insects. Since there are many kinds of insects and they cause many different kinds of problems, there are many kinds of insecticides to control them.

In 1964, the United States Department of Agriculture did a random sample survey of farmers that indicated that they used a total of approximately 2 million pounds of 12 different insecticides. This accounted for about 85% of the total volume of insecticides used in the United States that year. Toxaphene was used in largest volume, followed closely by DDT. These two materials made up 46% of the total pesticides used in 1964. The survey also indicated that farmers applied two-thirds of the total quantity of all insecticides used on farms on three crops: cotton, corn, and apples (fig. 5).

Insecticides may be classified in several different ways. One widely used system is based on the mode of entry of the insecticidal agent into the insect—stomach, contact, and respiratory poisons. Stomach poisons are ingested by the insect and kill primarily by gaining entry through the digestive system. Their effectiveness is generally limited to the control of chewing insects. Contact poisons are absorbed through the body wall requiring direct contact with the insect to kill. They are usually required against sucking insects. Respiratory poisons enter the tracheal or respiratory system in the form of gas fumigants and are most effective against insects found within an enclosure. Several contact insecticides are rather volatile (vaporize readily), so they also have the ability to act as fumigants.

Because of the large degree of overlap found when using this system of classification, insecticides are more frequently discussed in terms of their chemical nature. The major divisions are inorganic and organic. Organic insecticides are further broken down into oils, botanicals, and synthetic compounds. The synthetic compounds are by far the most widely used and are further subdivided on the basis of their chemistry.

Inorganics

Although inorganic insecticides have largely been replaced by more efficient organic compounds, some still find a place in agricultural pest control. Lead arsenate has been used primarily on trees and shrubs to control chewing insects but is seldom used anymore. It may also be used in baits for the control of ants and cockroaches. Other inorganic insecticides occasionally used are calcium arsenate, various sulfur derivatives, and paris green. Thallium sulphate is used in baits for ants.

General use of inorganics is restricted because of toxicity to man, persistence, and the advent of newer and better insecticides.

Fig. 5—Pesticides have a part in the production of an abundance of high-quality fruits and vegetables found in this country.

Organics

Oils

Oils are used in an emulsion (suspended in liquid) and are employed as insecticides in a number of ways. They may be used as solvents or carriers for insecticides, e.g., diesel fuel in aerial applications. Oils also serve to carry insecticides over water for mosquito control, or even oil alone may be used for this purpose. For example, MLO (mosquito larva oil) or oil-base sprays use no water. Highly refined oils, which are relatively nonphytotoxic, are applied to tree foliage. These are known as summer oils and are effective in controlling aphids, mites, and scale insects on fruit trees. The dormant oils, which are less refined, are restricted in use to application when no foliage is present. They are effective in eliminating overwintering eggs of mites and aphids and in controlling scale insects.

Materials being used as carriers or inert ingredients are being examined more carefully. Recent research indicates that some of these materials have had detrimental effects on nontarget insects.

Botanicals

A number of plant extracts are in active demand as insecticides despite the variety of synthetic organic compounds now available. These extracts, or botanicals, break down into harmless compounds soon after application and, with a few exceptions, may be handled with relative safety. They are quite specific in their effectiveness, being limited largely to soft-bodied insects such as aphids, thrips, and certain caterpillars, particularly in the younger stages. The more important toxicants include pyrethrins, rotenone and a few related compounds. All are of complex structure, and there has been little success in their development by synthesis, with the notable exception of allethrin, a synthetic pyrethrin.

Pyrethrin and allethrin are formulated as dusts, sprays, and aerosols, usually with a synergist, which is a material that increases the toxic action of an insecticide. Pyrethrins are noted for rapid knockdown of insects. Low mammalian toxicity makes them very suitable both as livestock and as household sprays. Rotenone kills by inhibiting oxygen utilization by the insect. It may be used with relative safety around most animals, although swine are highly susceptible to its toxic action. Its greatest use as an insecticide has been for control of cattle grubs and external pests of livestock. Other botanicals of lesser importance include sabadilla, ryania, barthrin, dimethrin, and nicotine. Practically any of these would receive more use if they were more readily available and less expensive.

Synthetic Organics

The synthetic organics dominate the insecticide field today. Rapid developments make an up-to-date classification difficult, but they can be broadly grouped into general chemical classes.

The organochlorines or chlorinated hydrocarbons have been widely used since 1945. General characteristics of this group are the prolonged residual effect by both contact and stomach action, essential insolubility in water, and little or no tendency to be absorbed systemically into plants. Some have shown effective persistence for over 10 years in tests where soil treatments were used as in termite control or in controlling soil insects such as wireworms. Contrary to popular belief, the organochlorines are rather specific in their action (as are most groups of insecticides), being highly poisonous to insects in certain groups and comparatively ineffective in killing others.

Resistance to these insecticides has developed in a growing number of pests during their period of use, possibly because they have been extremely effective and used for a long period of time. The development of resistance to one organochlorine is usually followed by resistance to others. As with most other insecticides, hazards to applicators are minimal when these insecticides are used according to directions, with the exception of endrin, which must be handled with extreme care.

The problem of illegal residues persisting after harvest usually comes from this group of insecticides.

Chlorinated Hydrocarbons—The chlorinated hydrocarbon insecticides include a rather diverse group characterized by the presence of chlorine, hydrogen, carbon, and occasionally oxygen and sulfur. On the basis of chemical structure, it is more appropriate to subdivide the chlorinated hydrocarbon insecticides into diphenyl compounds (the DDT group); the cyclodienes (aldrin, dieldrin, chlordane group); and a miscellaneous group composed of BHC, lindane, and toxaphene. All appear to be nerve poisons causing hyperactivity and paralysis. However, it is likely that they exert their toxic effects through various mechanisms of action.

The biological activity of some of these insecticides may vary greatly, even among those within the same group. The DDT group, for example, contains some that are very specific for mites (Kelthane and Tedion). Kelthane differs from DDT only by the single substitution of a hydroxyl for a hydrogen in the molecule. As a result, Kelthane is toxic to mites, but not insects. DDT kills insects but not most mites.

The attraction that several of the chlorinated hydrocarbon insecticides have for fat is certainly one of the most important factors leading to the current concern for pesticides in our environment. This characteristic is shared by DDT, DDD, aldrin, dieldrin, heptachlor, lindane, BHC, endrin, chlordane, and toxaphene. However, only a limited number of these insecticides or their metabolites occur frequently in man and animals, and these are principally DDT, dieldrin, and heptachlor. Thus, one should not conclude that just because an insecticide is classified as a chlorinated hydrocarbon, it is widely distributed and magnified in the environment.

Many of the chlorinated hydrocarbons are very toxic to fish. In fact, one of them, toxaphene, was widely used as a fish poison up until the early 1960s. The extremely low water solubility of the chlorinated hydrocarbons minimizes hazards of runoff from treated land unless the runoff is accompanied by soil erosion. However, the persistence of this group of insecticides allows them to run off over a longer period and during repeated flows of water.

DDT: United States DDT production during 1967 was 103 million pounds, down approximately 27% from 1966. Exports during 1967 were 82 million pounds, down approximately 10%. Over half of all DDT exports were in the form of 75% wettable powder used primarily for mosquito control. In 1967, five countries (India, Thailand, Brazil, Nepal, and Mexico) received over two-thirds of the export tonnage of this formulation. Economic Research Service surveys indicate that the U.S. output of DDT in the late 1960s was approximately 40% less than the peaks reached between 1960 and 1963. DDT has been replaced by less persistent pesticides in many States. Of special significance has been the reduction in its use for large-scale forest insect control programs, mosquito control programs, and many agricultural uses (fig. 6). Part of this reduction is due to the appearance of resistance in some pest species.

Large amounts of DDT have been used in this country for the control of insects in the production of food and fiber, for control of mosquitoes and gnats, and for other limited purposes. Substitute products are usually more expensive and sometimes less effective. Many of the substitutes have acute toxicities representing greater hazards to the user than DDT. Other substitutes have a lower mammalian toxicity but present a much greater hazard to pollinating insects. Still others are initially more toxic to fish and wildlife, though they may not accumulate in body tissues like DDT.

It is not possible to summarize the advantages and disadvantages of substitute chemicals that are presently available since there are no general substitutes. Several available partial substitutes have a variety of disadvantages, including increased mammalian toxicity, lack of tolerances on food commodities (no residue allowed on food), decrease in insecticidal value, high cost, increased toxicity to bees and pollinating insects, and increased toxicity to fish and wildlife. The biological impact of large-scale use of many substitute chemicals is as yet unknown.

The usefulness of noninsecticidal control techniques has been demonstrated on a laboratory scale for several of the major economically important insects. The use of the sterile male technique and attractants plus pesticides have been used for the control of the screw worm in cattle and of certain fruit flies, both in the U.S. and on certain Pacific islands.

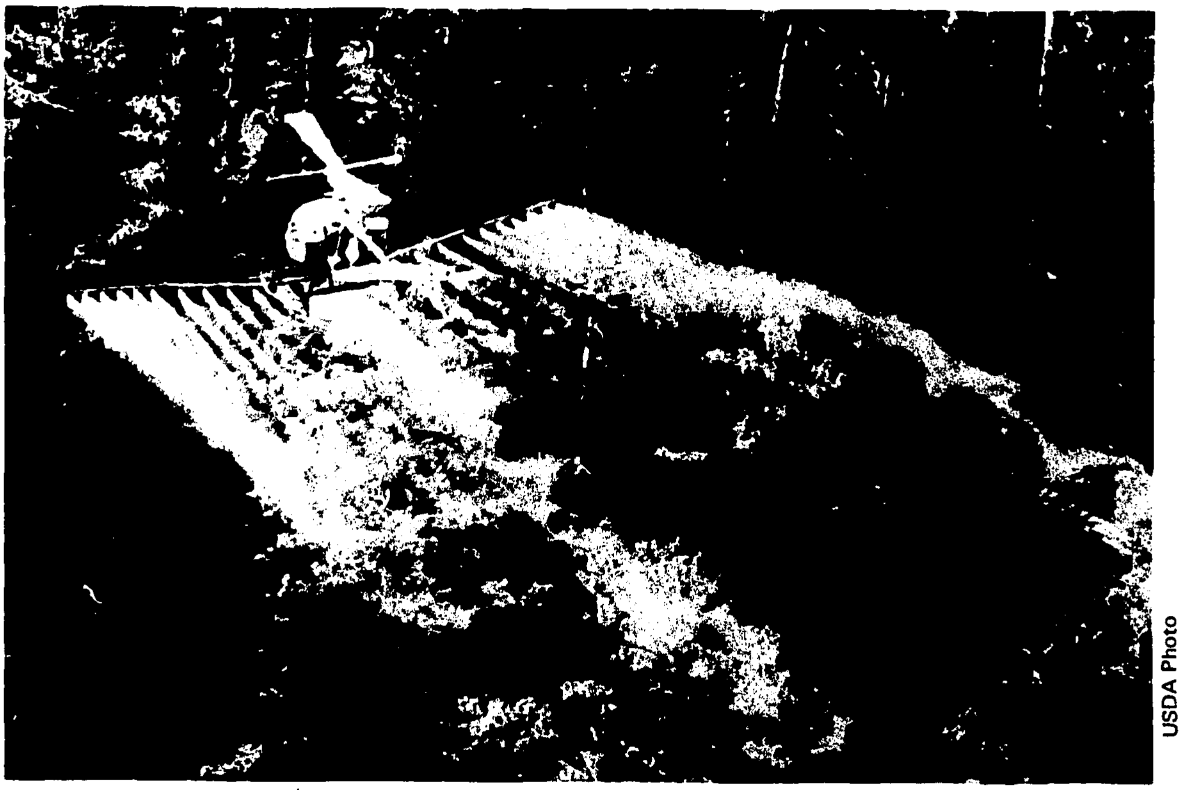


Fig. 6–Spraying by helicopter to suppress the Douglas fir tussock moth infestations in Oregon.

Although the total production of DDT is declining, it is estimated that more than half of the total U.S. production of DDT is exported by AID and UNICEF for malaria eradication. It is evident from production data that the use of DDT in domestic pest control programs has decreased dramatically, and this appears likely to continue.

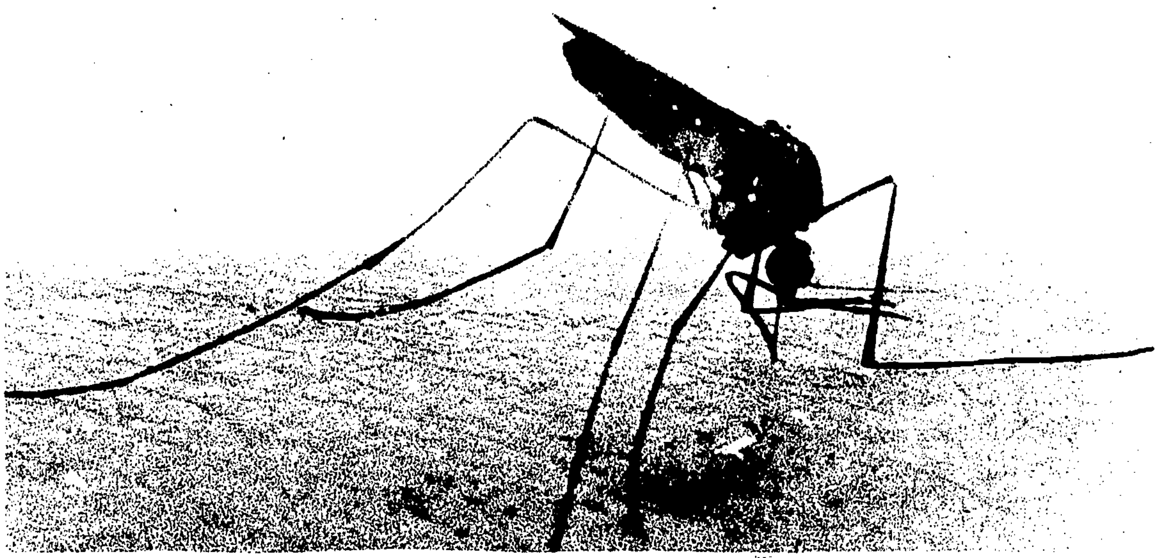
It is reported by well-informed scientists that, as far as insect vectors of disease are concerned, there are none known that are normally susceptible to DDT that cannot be controlled with a substitute. However, stopping the production of DDT in this country would be a very serious blow to foreign malaria eradication programs now being supported largely by AID. This is largely because international malaria control programs are simplified by the prolonged contact toxicity of DDT to adult mosquitoes.

It has been suggested that banning the use of DDT in this country and at the same time sending it overseas for malaria programs would be looked on with disfavor by recipient countries.

Methoxychlor: In comparison with DDT, methoxychlor production and use are at much lower levels. Use levels have been quite stable over the past 15 to 20 years, although its pattern of use has varied and changed somewhat over this period. Currently, about 75% of the methoxychlor sold is used for fly control on cattle and in farm buildings, with the remainder divided between farm crops, control of elm bark beetles (dutch elm disease), grain bin treatment, home gardens, 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.

Restrictions on use of the "persistent" insecticides should have only minor effects on use of methoxychlor because: (1) methoxychlor is not very effective against a number of the pests controlled by these compounds—for example, soil insects such as corn rootworm, wireworms, etc.; and (2) other compounds, such as various organophosphates or carbamate insecticides, are available and registered for many uses and would probably be used more extensively if the persistent insecticides were banned.

A moderate increase (5%-10%) is projected in the uses of methoxychlor for which it already is accepted (cattle, farm buildings, etc.) plus possible increases for area control of mosquitoes, blackflies, etc. (fig. 7). Methoxychlor has a close structural relationship to DDT but is less toxic to mammals and readily metabolizes to nonpersistent breakdown products. It has an oral LD_{50} to the rat of 6000 mg/kg, as compared with 250 mg/kg for DDT. (The higher the LD the lower the toxicity.) LD_{50} refers to the quantity of pesticides that, when administered in a single dose, is lethal to 50% of a group of test animals. The toxicity or ability of pesticides to poison will be discussed in a later section of this unit. Most important, methoxychlor is much more rapidly eliminated from the animal body and, thus, is not accumulated in fat or involved in food-chain magnification. Of course, it is less persistent than DDT, which renders it less effective for insect control in some situations.



USDA Photo

Fig. 7—Chlorinated hydrocarbon materials have been effective against mosquitoes.

Aldrin: This compound has been an effective and extensively used soil insecticide. Roughly half of the U.S. corn acreage treated with soil insecticide in 1968 was treated with aldrin. The particular insects of economic importance that are 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. The highest sales for aldrin were in 1966. In 1968, sales of aldrin dropped 30%, and by 1972 the estimates indicated a reduction of 60% from the highest sales year. Again, part of this reduction was due to insect resistance to this compound.

Dieldrin: This compound is used widely to control a variety of pests, especially when a long-lasting residual effect is desired. These residual uses for dieldrin include its application for termite control; insect control on lawns, turfs, ornamentals, and flowers; and, at the present time, household residual sprays and long-term mothproofing of fabrics.

In 1968, 81% of the aldrin and dieldrin agricultural use was for corn soil insects. Other agricultural uses made up 11%, and nonagricultural speciality uses, including termite control, Government programs, and so forth, an additional 8%.

The highest sales year for dieldrin was in 1956. Use steadily decreased because of resistance in the cotton boll weevil and certain other agricultural pests. This is a 70% drop in a 12-year period. Estimates indicated that use would drop another 10% by 1972. Practically all remaining uses are for nonagricultural purposes.

Endrin: The major domestic use for endrin is as a cotton insecticide. The projected use of endrin for this purpose indicated a decrease between 1969 and 1973 as a result of increased insect resistance. Projected use for endrin in international areas indicated a relatively stable use pattern or, possibly, a slight decrease. All uses of endrin in the U.S. are on a nonresidue basis, meaning that there can be no detectable residue on the crop at harvest. Substitute insecticides for endrin are being evaluated in many developing countries. However, economic factors have limited the introduction of substitute materials: for example, in India, studies indicate that substitute insecticides for control of rice and cotton insects would increase the cost of treatment 80% to 95%.

Heptachlor: This compound is primarily a soil insecticide. It is anticipated that the heptachlor used in the U.S. will be primarily for control of the soil insect complex in corn, which will represent between 55% and 75% of the domestic use.

The second most significant use of heptachlor is in the commercial pest control field. Presently, about 15% is used primarily for structural termite control; this is expected to increase to some 34% by 1973. In 1960, there was a 50% decrease in the use of heptachlor over 1959 in response to the Food and Drug Administration's concern for the residues of its metabolite, heptachlor epoxide. An important use for heptachlor in early years was the control of alfalfa weevil. A significant reduction in the use of heptachlor occurred between 1963 and 1964 as a result of the residues reported in milk and subsequent removal of heptachlor for use on alfalfa.

Chlordane: The agricultural use of chlordane is primarily as a soil insecticide. It has been especially important in the home, lawn, and garden pest control markets. These markets represent its major use, which was estimated at about 70% of the total use between the years 1969 through 1973. Approximately 50% was estimated to be used in the pest control market, primarily for structural termite protection, and about 10% in home, lawn, and garden uses, primarily for turf treatment. About 30% was estimated for agricultural uses.

Toxaphene: This material has been registered for use on many crops and has been used extensively. It is a fairly persistent contact and stomach insecticide with an oral LD_{50} of 90 mg/kg for male rats and 80 mg/kg for female rats. Toxaphene is readily absorbed through the skin, so it is particularly hazardous to the applicator.

Organophosphates– The organophosphate insecticides are all derivatives of phosphoric acid. You may see them variously referred to as organophosphate or OP insecticides. Examples in this group include parathion, malathion, diazinon, phorate, TEPP, etc. All are inhibitors of cholinesterase enzymes, which are found in man and other animals as well as insects. Some of these enzymes are essential for the proper function of the nervous system, and inhibition causes lack of coordination and death.

Incidentally, cholinesterase inhibitors are not a unique invention of man. These have long existed in nature. A number of alkaloids inhibit cholinesterase, including solanine, which is found in black nightshade and Irish potatoes. It generally occurs to the extent of only a few parts per million in market potatoes, but potatoes that are green from exposure to sunlight, old tubers, and especially the small sprouts common on stored potatoes may result in fatal poisonings.

The organophosphates as a whole do not have a long residual action. This is undesirable where a long period of protection is needed, but many of the organophosphates are valuable when treatment is necessary close to harvest or to control insects that are resistant to the chlorinated hydrocarbons.

Although all organophosphate insecticides have similar structures and have the same mode of action, they often have other properties that are quite different. Parathion, for example, is relatively persistent. Residues may not reach a safe level on a food crop for several weeks after its application. On the other hand, TEPP breaks down so rapidly after application that a crop may be harvested 3 days later. It has a half life in water of only 8 hours.

Organophosphate insecticides can be divided into three groups or classes: heterocyclic derivatives, which include Co-Ral (coumaphos), Dursban, diazinon, Guthion (azinphosmethly), and others; phenyl derivatives, which include Nitrox (methyl parathion), Thiophos (parathion), Ronnel, Baytex (fenthion), Abate, Ciodrin, plus a large number of lesser importance; and aliphatic derivatives, which include such compounds as Dylox (trichlorfon), Dibron (naled), Vapona (dichlorvos), Phosdrin (mevinphos), Bidrin (dicrotophos), Systox (demeton), Thimet (phorate), Meta-Systox-R (oxydemethomethyl), malathion, Cygon (dimethoate), plus a number of others.

Parathion and several other OPs are very toxic to mammals as well as insects. Others are more selective, being only slightly or moderately toxic to mammals. Malathion is one of these selective insecticides. It is only slightly toxic to mammals because their livers contain an enzyme that is able to detoxify malathion before it can reach the nervous system. This enzyme is lacking, or nearly so, in insects.

Several of the OPs are systemic when applied to plants. That is, they are absorbed and transferred within the plant so that mites or insects may be killed at some distance from the application site. Application may be to the seed or roots of plants, as is commonly done with Thimet or Di-Syston, or to the foliage with materials such as Systox, Cygon, or Meta-Systox R.

Advantages of plant systemics may include longer residual action and comparative safety to insect and mite predators and parasites, particularly when applications are made to the seeds or roots.

There are also systemic OPs that can be fed or applied to livestock to control certain insect pests. These include Ronnel, Co-Ral, and Ruelene. When used as directed, they are not harmful to animals, even though present in sufficient amounts to kill internal and/or external insect parasites.

The OP insecticides are broken down by the action of enzymes, sunlight, air, and moisture. They are detoxified in animal tissues and eliminated rather than being stored in fatty tissues as are some of the chlorinated hydrocarbon insecticides. In man, parathion is broken down by enzyme action, and one product in urine can thus serve as an indicator of parathion exposure. Microroganisms in the rumen of cattle and in soil can also transform parathion into harmless products.

Most of the OP insecticides are highly toxic to fish and should be kept away from aquatic areas. However, under certain conditions of use, some may be deliberately applied to water without any adverse effects. Methyl parathion, for example, has been used to control gnats in Clear Lake, California, without apparent harm to fish or wildlife in the area. Precise timing and concentration are undoubtedly very important in determining the safety of this use.

Carbamates—The carbamate insecticides are esters of carbamic acid. The best known of this group is Sevin, which is effective against several species of lepidopterous pests as well as other insects. Carbamate insecticides of economic importance at this time include Baygon, Carzol, Furadan (carbofuran), Temik, and Zectran. The latter three are plant systemic materials and more highly toxic to man and animals than the others. Other examples of carbamate insecticides are Bux-10, Lannate (methomyl), and several others of lesser importance. It should also be noted that certain fungicides and herbicides are also carbamates, but they have distinctly different structures than the carbamate insecticides.

Carbamates act by contact or stomach poisoning and are not vapor toxicants. Their major area of use is on agricultural crops where recommended application rates range from 1 to 10 pounds per acre. The chief exception is Baygon, which is restricted to use by pest control operations for spot treatment in the control of cockroaches and other pests of public health importance.

Like the organophosphate insecticides, the carbamate insecticides are inhibitors of the enzyme cholinesterase. However, unlike the organophosphates, this inhibition is readily reversible. In other words, recovery from poisoning is much more rapid.

Studies with radioactive-labeled materials have shown these carbamates to be rapidly metabolized and eliminated from animals. Usually from 70% to 80% is excreted in the urine within 24 hours. They are not particularly persistent in plants or soils, and there is little, if any, storage in animal tissues. There is no evidence of biological magnification.

Sevin (carbaryl) is especially desirable from the standpoint of its low toxicity to humans and wildlife. However, it is very toxic to a number of beneficial organisms, especially bees and certain mite predators, limiting its usefulness in many agricultural areas.

Miscellaneous Insecticides

There are several insecticides available that do not fit in the above-mentioned groups. They typically have a more limited activity spectrum and are not as widely used. This group includes such materials as creosote and pentachlorophenol, which are used primarily to prevent termite damage to fence posts and foundations. Activity of these compounds is in large measure repellancy. Fly sprays for use around the home and in livestock structures may contain organic thiocyanates, Lethane, or Thanite.

Several fumigants are available and are used both in agriculture and for public health. These include methyl bromide, hydrogen cyanide, and paracide (paradichlorobenzene), which are applied at about 1 pound per 1000 cubic feet of area.

Fungicides and Bactericides

Fungicides and bactericides are toxic to fungi and bacteria. With plant diseases, these chemicals act to prevent the plant from undergoing detrimental effects of the particular disease. To be effective, the fungicide or bactericide must be capable of preventing a disease from becoming established or arresting the disease if it is already present. Most prevent rather than arrest disease. An effective material to be used on crops or desired plants must be relatively safe to the crop and be of low hazard to the consumer of the product and applicator of the compound.

Bactericides (disinfectants) are widely used to kill bacteria. For good results, it is important to thoroughly clean an area before applying a disinfectant (fig. 8).

USDA Photo

Fig. 8—Bactericide being applied to a well-cleaned truck bed will ensure maximum sterilization.

Inorganics

The inorganic fungicides are the oldest known fungicides and, despite the onset of new synthetic organic compounds, are still relied on by many growers. Their use is almost completely restricted to agriculture, with some application in the golf course and turfgrass industry, but with only minor penetration into the home and garden market.

Examples of inorganic fungicides on the market are bordeaux mixture, copper sulfate, copper oxide, copper zinc chromate, sulfur, lime sulfur, mercuric chloride, Clorox, cadmium chloride, plus a few other related compound mixtures.

Antibiotics

Some effort has been expended on the development of antibiotics as fungicides and bactericides to control diseases of plants. A number of materials have been discovered but are not ready for commercial use. One of the major problems has been phytotoxicity. Agrimycin (streptomycin) is a bactericide that has proven itself to be an effective control agent. Actidone (cycloheximide) exhibits similar activity as a fungicide.

Mercury Organics

Organic mercury compounds have been used as fungicides for seed treatments and for bulb and corn treatments. A few organic mercury compounds are used as foliar sprays. Areas of use have been chiefly agricultural with some use in specialty areas such as golf courses and the sod industry. Examples of products using organic mercury formulations are phenyl mercuric acetate, Semesan, Ceresan M, Panogen, Chipcote 25, Emmi, and Memmi. These uses of mercury have all been cancelled.

Other Metal Organics

Several other metal organic fungicides are available, chiefly for use in treatment of handling, harvesting, and storage equipment. They also are used to prevent rot and mildew in wood and fabrics. Some, such as Du-Ter, are applied to seeds or to plants, such as potatoes, as foliar sprays. Other examples are copper naphthenate and copper quinolinolate.

Dithiocarbamates

The dithiocarbamate fungicides have their greatest use in controlling foliar diseases of agricultural crops. Many are also effective when used as a soil drench. They are, for the most part, the metallic salts of dithiocarbamic acid derivatives. The metallic salt form provides them with the necessary stability to remain effective long enough to control the target disease organism. Examples of dithiocarbamates being used today are Vapam (SMDS), Zerlate (ziram), Parzate (nabam), Manzate (maneb), Dithane Z-78 (zineb), Arasan (thiram), Fermate (ferbam), and Polyram (metiram).

Chlorinated Fungicides

Chlorine-containing fungicides are effective against a large number of agricultural crop diseases. They may be used as foliar sprays, soil drenches, seed treatments, or dormant sprays. They are effective against turf diseases, powdery mildew, scab fungi, and several other pathogens. Examples of this class of fungicides are Penta (PCP), Terrachlor (PCNB), Hexachlorobenzene, Captan, Difoltan, Phaltan (forpet), Phygon (dichlone), Lanstan, Spergon (chloranil), Dyrene, Daconil 2787, Terrazole, Demosan, and Botran (dichloran).

Miscellaneous Fungicides

There are a number of fungicides of variable chemical nature that fall into a miscellaneous grouping. They are used both in agriculture and in the sod and turf industry. Examples are Karathane (dinocap), Dexon, Cyprex (dodine), Diphenyl, Dowcide A, Glyodin, and creosote.

Herbicides

There are over 100 different chemicals or combinations of chemicals that are used effectively as herbicides. Farmers are given help in selecting herbicides (fig. 9). The University of Illinois prepared an outline of three ways that herbicides could be classified; the outline was published in the March 1970 issue of *Farm Technology*. The three ways they listed of classifying herbicides were: time of application, mode of action, and chemical grouping.

Fig. 9—A state extension specialist tells fruitgrowers about methods used to evaluate herbicides in orchard weed control.

Time of Application

Some herbicides are applied before the crop is planted. Some require a period after application before certain crops can be planted. Applications before planting are referred to as preplant. An example of a preplant material is Treflan (trifluralin).

Preemergence is the term used to specify that the herbicide is applied after planting but before the plant emerges. Examples of a herbicide used for preemergent application is Princep 80W or Princep 4G (Aimazine).

Postemergence is the term used for applications after the crop has come up. Postemergent materials can be divided into two groups—those that are sprayed over the whole crop and those that are directed so as to miss the crop or hit only part of the crop being sprayed. Some postemergent sprays have to be incorporated into the soil.

Mode of Action

Some chemicals are quite selective and kill only a few kinds of plants. Others may kill all but a few kinds of vegetation; use of atrazine on corn is an example. Some are selective when limited quantities are applied but provide total vegetative control in greater quantities. Other chemicals provide total vegetative control even in rather small quantities. The total vegetation control herbicides, often called soil sterilants, are chemicals that prevent all plant growth when present in the soil. The length of time for effectiveness may range from less than 48 hours to more than 2 years.

Some herbicides are effective only if sprayed on the foliage of the plant. Others are effective if they are sprayed on or incorporated into the soil.

Contact herbicides kill only plant parts that they contact directly. Generally, the effects are acute and the plant dies quickly. Differences in plant structures may allow contact herbicides to be selective in their action or they may be nonselective and kill all plants.

Systemic herbicides often have lethal effects some distance from the point of application. They can be absorbed by either the foliage or the roots and may be translocated throughout the entire plant system. They are usually selective in their toxicity, and they usually have a chronic effect on susceptible plants.

Some herbicides stop germination while others act as photosynthetic inhibitors. Photosynthetic inhibitors act to eliminate or reduce photosynthetic activity (photosynthesis).

Mode of action is important in selecting a herbicide for use. The USDA and universities do a great deal of research on mode of action. This research is then made available to the public.

Chemical Grouping

Inorganics

Inorganic herbicides are derivatives of inorganic acids where hydrogen has been replaced by a metal. In sufficient concentration, these provide a contact burning effect. Exampies are sodium arsenite, calcium arsenate, sodium chlorate, and sodium borate.

Metal Organics

Metal organic compounds include those having a metal ion complex combined with an organic portion of the molecule. These compounds are usually used to control large areas of weeds such as on railroad and highway rights-of-way. A few are selective and are used to control crabgrass in desirable turf lawns. Examples are disodium methane arsenate, cacodylic acid, and several other similar products.

Carboxylic Aromatics

The large group of synthetic carboxylic aromatic herbicides includes two characteristic groups: a carboxyl group and an aromatic group. Their activity includes contact, systemic, and soil sterilant action, depending upon the compound and the rate and method of application. They can be divided into five types: phenoxy acids, phenylacetic acids, benzoic acids, phthalic acids, and phthalamic acid herbicides.

Phenoxy Acid—The phenoxy acid herbicides are a selective group of compounds used for broadleaf weed and woody plant control. They are systemic in nature and in warm moist soil persist 30-60 days. They are only slightly toxic to man and other animals. Examples are: 2,4-D, silves, 2,4,5-T, sesone, MCPA, erbon, dichloroprop, and others.

Phenylacetic Acid—The single phenylacetic acid of note is fenac. It is used for a variety of purposes, including agriculture, aquatic weed control, and right-of-way weed removal. It is more persistent in the soil than the phenoxy acid herbicides but would not be expected to accumulate from one year to the next. It also has a low toxicity to mammals.

Benzoic Acid—The benzoic acid herbicides have a longer soil persistence than the phenoxy compounds and have a low toxicity to mammals. Their major use is in agriculture where they are effective against annual and perennial broadleaves and grasses. Several show some crop selectivity. Examples are Amiben, Banvel D (dicamba), Benzac (PBA), and Trysben (2,3,6-TBA).

Phthalic Acid—The phthalic acid herbicides are pre-emergence herbicides that prevent weed germination. They are persistent for only about 30 days in the soil, and they are relatively nontoxic to mammals. Examples are Dacthal (DCPA) and endothall.

Phthalamic Acid—The phthalamic acid herbicides are pre-emergence compounds with selective activity and are used almost exclusively for agriculture. They are relatively safe to humans and other warmblooded animals. No residual toxicity is expected to remain in the soil from one year to the next. The best example is Alanap (naptalam or NPA), which is available in several forms.

Aliphatic Acids

The chemicals in this group are aliphatic compounds containing a carboxyl group. They are grass killers with limited toxicity to broadleaved species. At low rates of 3 to 6 pounds per acre they are agricultural herbicides, but at 10 to 50 pounds per acre they are temporary soil sterilants. They are only slightly toxic to humans and warmblooded animals and present no health hazard under normal use. Examples are Dowpon (dalapon) and trichloracetic acid (TCA).

Substituted Phenols

Substituted phenols are used for contact killing of all weeds hit by the spray. They are applied to railroad and highway rights-of-way and industrial areas as well as on agricultural crops. They are also used as pre-emergence herbicides. Their persistence in the soil is only about 3 to 5 weeks, and they are not translocated in the plant. Examples are dinoseb (or DNBP) and pentachlorophenol. Their toxicity to mammals is considered moderate to very toxic.

Heterocyclic Nitrogen Derivatives

The heterocyclic nitrogen derivatives are agricultural herbicides with low mammalian toxicity. When applied at 1 to 4 pounds per acre, they demonstrate good selectivity, some possessing pre-emergence and some postemergence activity. At higher rates of 10 to 40 pounds per acre, a few are effective soil sterilants. At rates of less than 4 pounds per acre, and under a warm, moist environment, they seldom persist in the soil for more than 1 year. Examples are Aatrex (atrazine), Princep (simazine), Milogard (propazine), premetone, and amitrol.

Aliphatic Organic Nitrogens

Aliphatic organic nitrogen compounds can be subdivided into three general types: the substituted ureas, carbamates, and other amides.

Substituted Ureas—Urea is a common agricultural nitrogen fertilizer. Replacement of some of the hydrogen atoms in the urea molecule with other substituents has provided a number of effective herbicides. They are absorbed easiest through the roots and will normally persist in the soil 3 to 6 months at pre-emergence rates (1 to 4 pounds per acre) and up to 24 months at soil sterilant rates (20 to 50 pounds per acre). They are relatively safe to warmblooded animals and fish when used at agricultural rates. Examples are Telvar (monuron), Karmex (diuron), Dybar (fenuron), Lorox (linuron), Cotoran (fluometuron), Tenoran (chloroxuron), Herban (norea), and Tupersan (siduron).

Carbamates—A number of carbamates have been proven to be quite effective as agricultural herbicides. They are most effective in pre-emergence applications and are relatively nonpersistent in moist, warm soils. Although a few carbamate herbicides will cause skin irritations, they are considered to be moderately safe to humans and warmblooded animals. Examples are Vegedex (CDEC), Chloro IPC (CIPC), Eptam (EPTC), Tillam (pebulate), Sutan (butylate), Vernam (vernolate), Carbyne (barban), Ordram (molinate), and Avadex (dillate).

Amides—There are several amide derivatives used as herbicides in agricultural and home and garden products. They are basically pre-emergent herbicides with a soil persistence of 1 to 3 months. For the most part, they are only slightly toxic, but one, CDAA, is toxic to the skin. Other examples are Dymid (diphenamid), Betasan (bensulide), Lasso, dicryl, Clobber (cypromid), and Stam (propanil).

Dinitroanilines

The dinitroaniline herbicides are pre-emergence compounds effective against annual grasses and some broadleaved weeds. They are extensively used in field and horticultural crop weed control and turf. In warm, moist soil they have a persistence of 2 to 6 months. Their toxicity to humans and warmblooded animals is only slight, making them safe to handle. Examples are Treflan (trifluralin), Balan (benefin) and Planavin (nitralin).

Nitriles

The nitrile herbicides are used for pre-emergence broadleaved weed control in small grains and also in orchards and nurseries. Moderately toxic to mammals, they range in soil persistence from 1 month to over 2 years. Examples are Buctril (bromoxynil), Certrol (ioxynil), and Casoron (dichlobenil).

Miscellaneous Herbicides

Herbicides falling into a miscellaneous category include uracil derivatives, chlorinated compounds, aldehydes, and others. The group includes at least two compounds, paraquat and diquat, possessing higher mammalian toxicity. Others of this group are considered moderately toxic. They are used in agriculture as well as in industry. Other examples include Tordon (picloram), propachlor, Aqualin (acrolein), Pyramin (pyrazon), Sinbar (terbacil), and bromacil.

Damage by Herbicides

Considering all organic herbicides, available data indicate no problems involving biological magnification. They are generally only moderately toxic to fish. There are a few exceptions, but to the author's knowledge they have not been implicated in any fish kills. Adverse effects on other forms of wildlife might be expected through destruction of favorable habitat but not by a direct effect of the herbicides.

Nematicides

Nematode control requires the use of clean soil, clean planting stock, and sanitation. Chemicals used to kill nematodes must not only be efficient for killing the organism, but also must leave no residues harmful to plants. Preferably they should be easy to apply. The most effective nematicides have been those with fumigant action. The fumigant action may come from a gas confined at the soil surface or from volatile liquid or granular compounds actually placed in the soil (fig. 10). All are poisonous to man and animals. When the soil must be covered, the cost of application rises rapidly. Not only is more complicated equipment required to lay the cover, but there is the added cost of the covering material. The covering material is often plastic and must eventually be removed requiring still further expense.

Nematodes are long, round worms that are members of the class phylum Nematoda. These worms can be parasitic in animals or plants or may live in soil or water.

Halogenated Hydrocarbons

These nematicides may be injected into the soil or they may be gaseous fumigants applied to the soil surface under gasproof covers. They have a residual activity of about 1 to

Fig. 10—Applying nematocides to potato fields to control the golden nematode.

6 weeks during which time they can be harmful to plants. They should be regarded as moderately to very toxic to the applicator. Many are mixtures of two or more active compounds. Examples are Dowfume MC-33 (methyl dibromide + chloropicrin, D-D (dichloropropane + dichloropropene), Telone (mixture of chlorinated C_3 hydrocarbons), Nemagon (dibromochloropane), and ethylene dibromide.

Organic Phosphates

A special formulation containing 4 pounds per gallon diazinon controls soil insects and ectoparasitic nematodes of southern turf grasses.

Cyanates

Vorlex is a preplant soil fumigant that controls weeds, fungi, insects, and nematodes. At least 2 weeks must be allowed before planting a crop. No cover or water seal is required.

Thiophenes

An example of a thiophene nematicide is Penphene (tetrachlorothiophene or TCTP). It is recommended for controlling a number of nematode pests on tobacco. After 2 weeks, the soil must be aerated before the crop is planted.

Rodenticides and Mammalian Biocides

The interrelationships of man and animals have become increasingly complex as human populations have increased. As wildlife habitats have become altered, certain species have established new balances. Thus, some species have substantially increased in population density, often creating problems that adversely affect man's interests and welfare. There are numerous situations when control of predators and rodents is essential to protect agricultural and pastoral interests as well as human health and safety.

Of the various kinds of nuisance, destructive, disease-carrying, or predatory mammalian pests, rodents are the main targets of control (fig. 11). A number of chemical control measures have been developed for rodents, many of which can be used on other mammalian pests such as coyotes, skunks, raccoons, etc. Compounds that are toxic to rodents are usually also toxic to humans and should be handled with utmost caution.


USDA Photo

Fig. 11—Rats eat and destroy large quantities of food each year.

Inorganic

There are a number of inorganic compounds that are effective against such pests as rats, mice, moles, and gophers where they are problems. Although most often used as 1% to 2% baits, a few are active as fumigants. Examples of some inorganic rodenticides are arsenic trioxide, arsenic sulfide, barium carbonate, calcium cyanide, zinc phosphide, thallium sulfate, and sodium fluorosilicate plus zinc cyanide.

Botanical

Certain plant extracts have toxic activity toward rodents when used in baits at 0.5% to 1%. One of these, red squill, is specific for rats and nontoxic to other warmblooded animals when used at specified rate ranges. Strychnine, in both the alkaloid and sulfate forms, is used chiefly in poison baits set for squirrels, gophers, rabbits, and some lesser pests.

Anticoagulant

The anticoagulant rodenticides are highly effective in controlling rats and house mice. They are essentially odorless and tasteless and are effective in low doses. Action is not rapid and usually three to five feedings from a 0.5% bait are required. Death is due to internal hemorrhaging. These baits are recommended for use only in protected situations where access by higher animals is prevented. Examples of this class are Fumarin (coumafuryl), Diphacin (diphacinone), Warfarin (coumafene), Pival (2-pivalyl-1,3-inandione), and Valone (2-isovaloyl-1,3-indandione).

Fluoride

The fluoride rodenticides are extremely toxic to warmblooded animals, and their application is restricted to use by licensed pest control operators. They are odorless, tasteless, and fast acting, chiefly affecting the heart, with secondary effects on the central nervous system. Two such compounds are in use: Compound 1080 (sodium fluoroacetate) and Fluoroakil 100 (fluoroacetamide).

Miscellaneous Rodenticides

There are a few other rodenticides available with a greater degree of selectivity toward rats. One of these, ANTU (2-naphthylthiourea) is specific for the Norway rat when used as a 1% to 2% bait. Another is a specific single-dose rat poison for Norway and roof rats. This compound, Raticate (norformide), is said to be nontoxic to a large number of other warmblooded animals.

Repellents

Repellents have two principal advantages. First, because they need not kill the pest species, the best repellents have low general toxicity and may be used safely on man, beneficial animals, and food plants. Second, they can provide protection for an individual man, animal, or plant without the necessity of destroying a huge segment of the pest populations, with all the expense, difficulty, and even hazard that this may involve.

Repellents also have some disadvantages. Because the pest population is not destroyed but only held at bay, the host must be completely and continuously covered with the repellents to obtain protection. Usually the repellents that protect man and animals are lost rapidly by abrasion, evaporation, and absorption through the skin, necessitating retreatment at intervals of a few hours or days at the most.

The uses of repellents include protection for domestic animals from biting flies. These may be combined with a low level of pyrethrins. Man uses repellents to help ward off biting and disease-carrying insects such as mosquitoes, flies, and ticks. Repellents are also used to prevent pests from infesting certain areas such as food and drink containers, as well as termite-susceptible structures.

Some insect repellents available are ethyl hexanediol (6-12), N,N-diethyl-m-toluamide, butoxy propylene glycol, dibutyl succinate, and octyl propyl sulfoxide.

Attractants

Chemical attractants and associated agents serve useful purposes as lures in traps. As insect attractants, they are used to detect pest infestations, estimate population densities, and aid in control of the pest either through traps or incorporated into poison baits.

Some chemical attractants are biologically active in extremely small quantities. This is particularly true for those associated with sexual behavior. Others are apparently feeding attractants. Although not always true, insect attractants are usually quite specific for a given species and often for a single sex of the species.

There are at least seven synthetic attractants available for use in control of fruit flies and melon flies. They are methyleugenol, anisylacetone, cuelure, siglure, medlure, and trimedlure. These have been very effective in aiding with Mediterranean fruit fly control. Other attractants are gyplure, bombykol, butylsorbate, and methyllinolate.

Plant Nutrients

At least 16 elements are considered necessary for the growth of green plants. These elements are divided into two groups on the basis of plant need for them. Those elements needed in the largest quantities are called macronutrients or major elements and are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), sulfur (S), potassium (K), calcium (Ca), and magnesium (Mg). The micronutrients or minor elements are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), boron (B), and chlorine (Cl). These elements (plant nutrients) are called essential because the plant cannot complete its life cycle without them and the disorder in the plant cannot be cured without the addition of the element.

Since the addition of these elements in proper quantities usually increases yields and profits, they have been used in greater quantities over the past few years. Since they are often cheaper and easier to apply per pound of available nutrients than manure, most farmers no longer try to obtain manure to apply.

Nutrients in the soil often become tied up in the soil and are not available for plant use. Nutrient uptake from soil by plants accounts for about 10% of the total dry weight of crops.

The increased use of fertilizers has come about partly because of demands for food in some countries and to improve production efficiency. Some of these added nutrients have, however, become resources out of place. The elements out of place are a concern to most environmentalists.

Drugs and Poisons

As in many other scientific fields, studies of animal disease and medication have increased rapidly over the past several years. The first real breakthroughs in animal medication came within the past century or so. Two of the major problems that existed were that a better understanding of animal diseases and the organisms causing them was needed, and at the same time we needed a better understanding of chemicals and drugs that could be used to help treat these diseases. Many of the remedies used for animal diseases, parasites, and even injuries have been shown in recent years to have little effect in ensuring an animal's good health. There are instances in which the common remedies of less than 100 years ago have now been shown to actually have a detrimental effect upon the animal.

Complicating research efforts has been the fact that the very same drug may affect different species of animals quite differently. For example, morphine will put dogs to sleep but causes cats to become restless and excited. Another example is the fact that chloroform is a fairly safe anesthetic for the horse but a dangerous one for the hog.

Drugs may be classified in many ways. It is important to know whether a drug affects only a small area where it is injected or if it will enter the blood stream and circulate throughout the body.

Drugs may be classified by the actions that they produce in the animal. A listing of such common categorizations would include stimulants, depressants, anesthetics, irritants, antiseptics, narcotics, and antibiotics. Drugs may have more than one effect, having a desirable effect in curing a disease while at the same time causing problems in another organ in the body. For example, turpentine is a fairly effective treatment for the coughing that accompanies certain types of diseases, but it is also an irritant to the kidney. The same drug may vary in its effects, depending on how it's applied. For example, alcohol when taken internally acts as a depressant, but when rubbed externally onto the skin acts as a mild stimulant. Some of the most active antibiotics have harmful side reactions, so they must be used with a great deal of caution.

Sometimes the treatment is merely replacing necessary constituents of the normal body. This can be done intravenously as the injection of a form of soluble calcium is used in cows as a treatment for milk fever. This kind of treatment has dramatic results in a cow that appears to be and may actually be near death, but may well be on her feet in 10 to 15 minutes after the injection is completed. Injection of hormones into animals suffering hormone deficiencies may likewise have speedy and dramatic effects.

Although it is theoretically possible to give animals medicine in all the ways that they can be given to humans, there are practical limitations. A good example is that many human medicines are taken orally. The best way to give many animals oral medicine is by mixing the medicine with the feed or with water. However, many sick animals will also be off feed, may not want to drink, and may not even lick at salt and other such materials. Some medications also have rather undesirable odors or tastes so that the animal will not eat them. In these cases, it is sometimes possible to disguise the odor or flavor so that the animal will still eat it. Thus, bad-tasting drugs administered orally to most farm animals have to be given as drenches with a dose syringe or injected directly into the stomach with a stomach tube. Pills, capsules, and boluses must be placed far back in the mouth if they are to be swallowed.

Because of the problems with other methods, more and more medication is being given by the hypodermic syringe (fig. 12). Most medicines that dissolve in water and are not irritating can be given in this way. As long as sterile syringes and needles are used to inject sterile solutions, there is little danger.

A goodly number of drugs are applied directly to the area to be treated. Examples of some drugs are ointments, lotions, and antiseptics applied to the skin, eye washes, and medications that are injected into the udder through the teat canal.

Keeping a few good medications around the farm may allow faster treatment of some diseases and save a trip for the veterinarian in other cases. However, for the most part, these drugs should be kept to a bare minimum and should be used only in emergencies. It is generally a good idea to consult a veterinarian as to which drugs should be kept on hand. In general, the high-powered, quick-acting, and severe drugs should be avoided.

USDA Photo by Forsythe

Fig. 12—Vaccine being given by hypodermic syringe to prevent black leg.

Parasites and parasitic diseases offer special problems. Because of the many different life cycles involved in parasites, generalized treatment procedures are impossible. Since most parasites are readily spread from one animal to another, entire herds or flocks must be treated at one time to eliminate the parasite, even for a short period of time. Since minor infestations of many types of parasites may go undetected, or at least be very difficult to detect without careful use of the microscope, medication is often given as a preventative measure at periodic intervals. Since these parasites have various numbers of hosts and go through varying types of life cycles, it is important to identify the period in their life cycle when they can best be attacked to get the most thorough eradication.

Chemical control measures are generally immediate in their effects, economical, and often simple to apply. If, however, other eradication means, such as good sanitation, can control the disease, it may be much more desirable to avoid the use of chemicals.

External parasites have been controlled by the use of many types of insecticides. Some of these, such as DDT, methoxychlor, BHC, lindane, and chlordane, have received considerable criticism. Many of these chemicals have long-lasting effects and may, therefore, wash into waterways and be carried long distances where they may build up in fish and other water life.

Some of these chemicals used to remove or eradicate parasites may find their way into milk, meat, or other livestock products. Many of the most effective chemicals can be absorbed through the skin of an animal, stored in fat tissues, or excreted in milk. This has made the avoidance of residues one of the chief concerns in the safe use of many kinds of parasite controls.

Like other agricultural chemicals, drugs have received their share of the headlines. Stories such as those stating that the use of stilbestrol in cattle rations is causing cancer in humans have been exaggerated and later corrected by statements of scientific facts. Some people only see the original article and are left uninformed about the true facts.

Another area of concern has been antibiotics. We have heard concern that indiscriminate use of antibiotics in animals may lead to the development of resistant bacteria. These resistant bacteria may then attack humans, so antibiotics will not be effective against them. Antibiotic residues in animal products such as milk, meat, and eggs may have undesirable effects in humans, including making antibiotics less effective for them in the future.

The primary responsibility of the livestock producer is to *use pesticides and medicated feeds according to the directions on the label.* He should pay particular attention to precautions and withdrawal periods prior to marketing. Careful consideration is given to scientific data from laboratory and field experiments to properly label chemicals before they are sold in interstate commerce. This is to ensure that harmful residues will not occur in food if chemicals are used according to label directions. It is important that a pesticide or medicated feed not be used for animals or pesticides used on crops other than those indicated on the label.

Feed manufacturers and dealers are part of the regulated industry, so, in the manufacturing and mixing of feeds, they must comply with all of the regulations of the Federal Food, Drug, and Cosmetic Act and its amendments. The feed and grain industry must keep informed on what substances are allowed as feed additives, the quantity to add to feed, and proper labeling of such feeds. If a livestock producer wishes to have feed mixed with an antibiotic, hormone growth promoter, or other chemical additive, he must cooperate with the feed dealer concerning his requirements and the limitations on what can be added to livestock feed. The feed dealer is responsible to see that the feed is not misbranded or adulterated, and the livestock producer is responsible to see that animal products—meats, milk, eggs—do not contain harmful or unlawful chemical residues.

Livestock producers who mix their own feed need to be as well informed as the feed and grain dealer about feed additive regulations and feed manufacturing practices in mixing additives in feed.

Remember that pesticide residues can enter animal feed products by indirect means such as application to forage and grain crops or by spraying in barns, milking parlors, or on chicken roosts. Remember also that these factors are taken into consideration in the labeling instructions on pesticides.

Always provide means for identifying feeds and chemicals. Whenever possible, store them in original packaging. If feed is purchased in bulk, label storage bins so that feed containing chemical additives will not be unintentionally fed to the wrong animals or be fed improperly prior to slaughter or marketing.

A veterinarian also has responsibilities. After the veterinarian has administered drugs to animals or poultry, he must inform the livestock producer of proper withdrawal times before marketing meat, milk, or eggs. When drugs are prescribed to be added to feed, the veterinarian as well as the livestock producer, must cooperate with the feed dealer to ensure compliance with the food additive regulations. If drugs are prescribed to be added to drinking water, the same requirements for prevention of harmful or unlawful residues in animal or poultry products apply as would apply if the drugs were administered directly to the animal or in the feed. Before administering drugs or prescribing them for use with livestock by any means, the veterinarian should find out if other drugs or chemicals are already being fed to these animals or added to their drinking water by the livestock producer. Combinations of drugs may be incompatible.

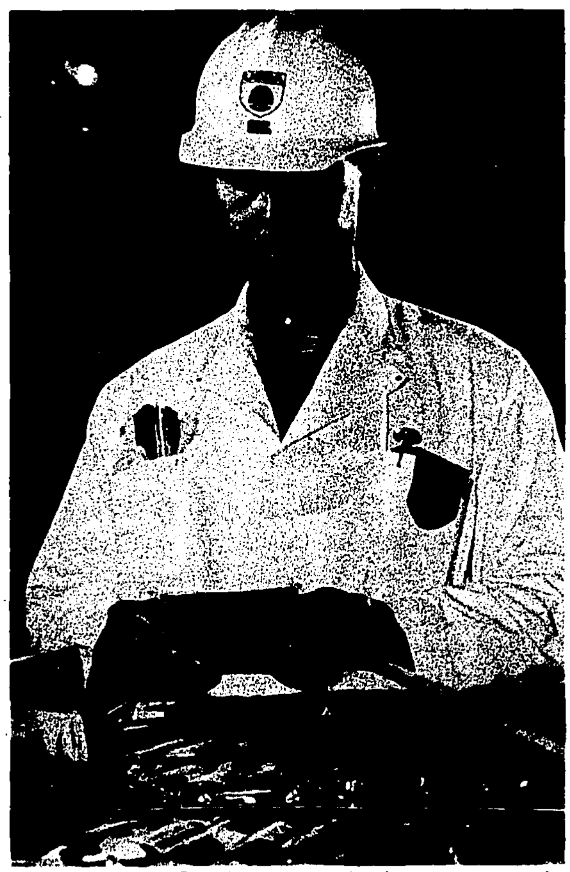
We cannot be absolutely certain of the effects that many drugs used in animals will ultimately have on man. Until we are at least relatively sure of the results, it would seem that great caution should be used. Much attention to drug problems has come about in connection with stories about thalidomide. This material, which was used in sleeping pills, was taken by pregnant women and caused deformities in numerous babies.

In the past, some drugs have been added to blood for transfusions. Manufacturers have stopped recommending this practice because of uncertainty as to safety.

Some drugs have been shown to have caused problems when they have been used by medical experts such as veterinarians. The problem is usually much worse when the same drugs are being used by people with less training. Farmers who use potent drugs without the advice of a veterinarian are asking for trouble. Drugs such as barbiturates, tranquilizers, hormones, and amphetamines require a prescription. Some of these drugs have been sold without prescriptions, and, in several cases, the sellers have been prosecuted by the Food and Drug Administration. Another very dangerous practice has been the purchasing of veterinary drugs for human use.

The result of banning or even curtailing the use of drugs would be widespread. Hardest hit would be the consumer who would have to pay higher prices for meat and other products.

We should also keep in mind that we have the safest, cleanest, and most wholesome food in the world (fig. 13). A brief trip to most other countries around the world and sampling their food and water will make us much more thankful for what we have. At the same time, we must recognize the need for more research.



USDA Photo

Fig. 13—A USDA inspector checks every step in plants where meat and poultry are processed to make sure the foods are properly packaged and will remain sound.

Other Types and Uses of Agricultural Chemicals

Improvement of Crop Performance

A relatively new development in agriculture is the application of chemicals to improve crop performance or to facilitate production, storage, and handling procedures. Knowledge of different uses and their effects is important. Some of the chemicals used to produce crops are the same as may be used as insecticides, herbicides, or for other purposes. Similarly, the same chemical may produce different effects on different crops or even opposite effects on the same crop depending upon the rate of application, stage of development of the crop, and weather conditions. All affect the amount of chemical absorbed by the plant. Slight variations in the use of these chemicals can have a significant effect on their performance. Equally important is the plant itself. Differences in age, stage of development, rate of growth, and vigor influence the response to whatever chemical is applied. Even small differences between varieties of the same crop can reflect major differences in response as well as susceptibility to injury.

Blossom and Fruit Thinning

Chemicals can be used to reduce the number of flower blossoms or fruit on a tree. Some of these are caustic materials that burn off the open flowers. Others are growth regulators that upset the physiology of the flower or fruit causing the seeds to die. When the seeds die, the fruits drop from the tree.

Reduced Premature Fruit Drop

The premature drop of apple and pear fruit can be reduced by applications of growth substances just before harvest. Note carefully the precautions on chemicals, rates, crops, and varieties before making applications.

Defoliants and Desiccants

Some chemicals are used to remove leaves and, in some instances, also dry down the top of the plant to aid harvest operations. A number of these chemicals have been used to defoliate cotton. Several types are used to facilitate the harvesting of some seed crops, potatoes, and nursery stock. One complication in their use on potatoes is discoloration of potato tubers at the stem end. This has been attributed to an overly rapid killing of the vine. Slower kill can be achieved by making two applications at reduced rates. In general, cultural and climatic conditions that result in low soil moisture at the time of application can also influence rate of kill and tuber discoloration.

Sprout Inhibition

Chemicals are applied to potatoes and onions to prevent sprouting in storage. Inhibitors should not be applied to potatoes or onions intended for use as seed. Treatments may be made either in the field, prior to harvest, or in storage after harvest.

Nutrient Sprays

Nutrients are not pesticides but are sprayed on crop foliage, particularly fruit trees. Because of their use and their application along with pesticides, attention is drawn to them in this section.

Nutrient sprays can cause injury. To reduce the hazard of injury: (1) Avoid application with oils or immediately preceding or following the application of oils. (2) Avoid high concentrations. (3) Do not combine with other pesticides. (4) Use only spray formulations. (5) Do not apply any nutrient unless it is deficient. Toxicities can occur.

Bird Control

Some of the most difficult control problems concern birds in cities, at airports, around homes, and those that gather in great flocks and cause damage to grain crops, animal feedlots, and truck and fruit crops. Some of the more troublesome species are pigeons, gulls, starlings, and blackbirds.

Avitrol (4-aminopyridine) controls nuisance and destructive birds as a treated grain bait. It causes individual members of the flock to utter distress cries that, in turn, causes other members of the flock to leave and avoid the "undesirable" place. It is used to control pigeons around city buildings, gulls at airports, and starlings in feedlots.

Another compound, Queletox (a formulation of Baytex insecticide), is also used to repel birds by affecting a few individuals that then frighten others away.

Also used for bird control because of their repellent action are anthraquinone and thiram. Thallium sulfate may be used in a bait to control starlings but is restricted to use by Government agencies because of dangerous cumulative poisonous properties.

Mollusc Control

There are several invertebrate poisons used to control molluscs where their presence is undesirable. They are relatively specific and are essentially nontoxic to fish and warmblooded animals.

Trash Fish Control

The use of piscicides is restricted to game and fish management for improvements to public waters. The main objective is to remove rough or trash fish prior to restocking lakes and rivers with more desirable game fish.

LEGISLATION, REGULATION, AND INTRODUCTION OF AGRICULTURAL CHEMICALS

A program has been in effect that allows a manufacturer of pesticides to place a relatively small amount of a product on the market. This gives him a chance to evaluate acceptance of the product and whether or not it fulfills a need in the marketplace. Through this program, a manufacturer can get an early estimate of whether the product will be a success. He can then better plan the facilities, equipment, and manpower necessary to produce the estimated requirements of the pesticide. This program also allows producers to try the material earlier under their field conditions. It allows the regulatory agency to observe use of the chemical under field conditions with producers using them. In addition, the manufacturer can observe the material used by producers while not being subjected to overwhelming liability.

In recent years, experimental labels have been used more widely. Under present procedures, it is necessary to account for all material placed under the experimental label and to provide biological results on the material used. This procedure is helpful, but a further step appears in order; namely, the limited sale in regular commercial channels of the material should be permitted or even made mandatory for 1 year prior to a full registration.

Efforts should be made to achieve label clarity. The purpose of the label on pesticide containers should be to identify the product, explain its use, provide adequate directions for its application, and to provide sufficient protection for the applicator.

The Mrak report gave the following six suggestions for improving label clarity:

1) The use of the product should be prominently displayed on the front panel in language familiar to the consumer; such as "Weed Killer," "Insect Killer," "Growth Regulator," etc.
2) The ingredient statement should be simplified. It should use common names only (and every active ingredient should have a common name) with no reference to chemical names as a footnote outside the ingredient statement, no reference to licensing agreements, no patent declaration, and no conversion to equivalents within the ingredient statement. Otherwise, the style for the declaration of ingredients could remain identical to current requirements of the EPA. The entire ingredient statement should be printed in such a way as to stand out from the rest of the label copy, i.e., printed with a contrasting background.
3) The label should specify what the product will and will not do. Organisms to which the product is hazardous should be indicated. For example, if a compound is known to be very toxic to specific types of animals such as fishes or birds this information should be highlighted on the label.
4) The label should be dated in some manner—date of manufacture, an expiration date based on product shelf life or stability, or, at the least, the date of label registration expiration.
5) It is recommended that an entirely new scheme of denoting relative toxicity be devised. The average consumer does not understand the progression from caution, [to] warning, to poison. A graphic or numerical representation of the degrees of oral and dermal toxicity should be developed to enable consumers to select less hazardous materials. Professional graphic communicators should be consulted on this project. Cautionary statements should clearly indicate the hazards without undue cautionary statements.
6) The manufacturer should be responsible for providing, on the label, information on how to handle spillage and other accidents. Complete instructions on the disposal of excess material and empty containers should be provided.

During the past quarter century of intensive organic chemical pesticide development, many products and product forms have been placed on the market. Today, with greater knowledge and better analytical tools, regulatory agencies would probably not allow some of these products on the market. Other products would require much more restrictive labels. The problem is especially acute in the area of homeowner products, where some highly toxic materials have been made available in small packages and where other products have borne unrealistically restrictive labels such as "Wear rubber gloves, mask, and goggles," or "Wear protective clothing." These have now been taken off the market for homeowners' use. Problems of shelf life, chemical stability, and physical stability have undoubtedly arisen in many of these products. Packaging materials of several years ago may be less satisfactory than would be permitted today.

At the present time, all pesticide products are registered with the EPA for a 5-year period. This expiration date does not now appear on the label. If it did, all obsolete stock not bearing a valid expiration date should be collected and disposed of. Collection, of course, causes the problems of financial responsibility to be brought forth. In many cases, the product might be returnable to the manufacturer. In cases where companies have gone out of existence, some other means of identification at public expense should be considered. It is imperative that a realistic and workable collection and disposal system for both pesticide and containers be established, and it is suggested that our present county agent offices for rural areas and public health officers for urban areas might be the appropriate collection centers. The removal of all obsolete stock from commercial channels would permit much better regulation of new products and would remove many potential hazards from the marketplace.

The development cost for any new pesticide is influenced by a number of factors. Some of these are related to the nature of the chemistry of the pesticide, but the most important influences on cost are those caused by the nature of our economy, i.e., labor costs, equipment costs, facilities overhead, etc., and the intended use of the new pesticide, i.e., food crop or non-food-crop use.

Although estimates of the cost of introducing a new pesticide vary greatly, many fall between $2 and $4 million. Many pesticide developmental programs are dropped at various stages and these costs also have to be considered. Adding these costs to the expense of developing a successful chemical would double or triple the cost.

An important part of every decision to develop a new pesticide is the competitive situation in the marketplace. Quite obviously, a new compound that has better activity, is safer or more convenient to use, or is less costly than competitive pesticides, has economic advantages that may make the market attractive. However, in many cases, these factors are unknown or difficult to determine accurately in the early stages of product development. Thus, a development decision is often made on the basis of limited knowledge of the true potential of the compound. Mistakes can be made that add to the development cost prorated against successful products.

When faced with decisions regarding the commitment of several hundred thousand dollars to compound development, research management often looks to the profitability of the market for the compound. When faced with such products as 2,4-D (selling wholesale at less than 40 cents per pound) and DDT (which sold at less than 18 cents per pound), management has difficulty in justifying a large research expenditure for a compound that has similar biological activity, at least until DDT was removed from the market. In addition, if adequate technical support is to be given a new product, there must be sufficient return to finance such support over at least the initial years of consumer use when he is learning to use the compound correctly. At the outset, when the ability of the new product to compete with existing and perhaps lower cost materials is unknown, only those compounds possessing distinct advantages over existing products have a chance for success.

Regulatory requirements can be expected to be increasingly more stringent as the years go by. As our technology advances, there will be many more questions to answer and requirements to be met. Each new pesticide must satisfy existing requirements, but each will also create new questions that must be answered.

In the quest to learn more about the impact of chemical pesticides on the environment, there will be new information developed that may alter present pesticide regulatory requirements. There will be more interest in persistence, metabolites in plants and soils, water and air pollution, etc. It can be expected that governmental regulatory agencies will constantly modify requirements that change patterns of agricultural technology and cultural practices. Just as the science of agriculture changes, the regulations governing pesticide development and use will change as needed. We must ensure that such changes are well founded and beneficial to agriculture and mankind.

As Federal Government regulatory requirements increase, it is safe to predict that there will be greater interest on the part of State and local governments. California has been a leader in the development of a State regulatory program; other States have a good beginning, and still others will follow suit. In all probability, most State regulations will follow Federal guidelines and will likely be less demanding. This makes it more difficult to produce a pesticide.

Two types of limited markets can be envisioned, one governed by crop acreage, the other by competition. In the first situation, the crop acreage potential for the pesticide is so limited as to make the market too small for an economic return on research cost, e.g., a herbicide for garlic or turnip greens. In the other situation, a large number of effective, low-cost products on the market so limit the potential for a new material of equal or slightly better activity that a return on research investment cannot be realized.

While somewhat unpredictable, we can expect greater awareness by the public of pesticides and their use. Everyone in Government and industry has a serious moral obligation to deal in facts to the public if pesticide and agricultural technology are to advance. Reporting and exaggerating the danger of pesticide use without equal treatment of the beneficial aspects of pesticides threatens to retard the advancing technology required to meet food and public health demands around the world.

BENEFITS FROM USE OF AGRICULTURAL CHEMICALS

Pest control is necessary to provide the food, feed, fiber, and other agricultural items required by the expanding world population. A good indication of what can be accomplished through the use of agricultural chemicals has been demonstrated during the past few years.

The *1966 Yearbook of Agriculture* has the following to say:

> Progress in protecting our food would not have been possible without the hundreds of measures for controlling the many kinds of insects found wherever crops are produced, and in their processing, transporting, and storage.
>
> Without insecticides, production of livestock would soon drop about 25 percent and production of crops about 30 percent. Food prices might then go up as much as 50 to 75 percent and the food still not be of high quality.

The U.S. consumer benefits from use of agricultural chemicals. He not only has an abundance of a variety of wholesome foods, but he can also buy these relatively inexpensively (fig. 14).

It is estimated that in the first 10 years that DDT was on the market 5 million lives were saved by it. Many more persons avoided countless suffering. In recent years, millions of lives have been saved each year by destroying insect vectors. Insect vectors transmit at least 27 diseases including malaria, yellow fever, virus encephalitis, typhus, trench fever, plague, cholera, scabies, and African sleeping sickness.

Malaria represents more dramatically the results of disease control through pesticides. In 1953, there were 75 million cases of malaria in India. By 1967, there were fewer than

Fig. 14—The school lunch program is one of many ways in which our nation is improving nutrition among children.

100,000 cases of malaria in India. This great victory over malaria took millions of tons of DDT. Malaria was also at one time a very important disease in parts of the United States. For example, there were 112 deaths and several thousand cases of malaria in California in 1910. Intensive control measures against the mosquito gradually reduced the disease, but it was not until DDT became available that malaria was virtually eradicated from this country.

Protection of personnel exposed to hazards of disease vectors and pests is a major problem for the military as well as for civilian hunters, campers, and others. Repellents now available provide protection from many biting pests and minimize the possibility of contracting arthropod-borne diseases (fig. 15).

Finally, control of certain species of pest insects, such as houseflies, cockroaches, and various innocuous mosquito species, contributes, if not specifically to public health, at least to a sense of well-being. Pesticides also provide, through the use of modern herbicides, the potential for control of allergy-producing weeds such as ragweed and poison ivy on farms, in cities, recreational sites, and other areas.

Many workers have been released from such hard and boring tasks as hoeing because of the use of herbicides. This has helped increase production efficiency, helping to lower production cost and hold down prices.

Use of pesticides, especially herbicides, has allowed many additional acres of land to be used for production. Other areas have been made usable for homes and recreation because pests have been controlled.

USDA Photo

Fig. 15—This scientist is demonstrating how quickly mosquitoes attack your arm when not protected with the insect repellant shown in the foreground.

EFFECTS OF AGRICULTURAL CHEMICALS ON NONTARGET ORGANISMS

The earth supports a complex system of living organisms of which man is an integral part. The system also involves the chemical and physical environments of the earth's crust, the oceans, the atmosphere, and the interfaces between them. In these environments, millions of kinds of organisms have evolved, each species with a specific set of requirements.

Certain basic ecological principles are well established. The green plants synthesize organic compounds through photosynthesis. Some animals feed on plants, some on other animals, and some on both. Bacteria and a few other organisms participate in the breakdown processes returning the chemical elements that can be reused and recycled. This master cycling is accompanied by lesser cycling of specific elements and compounds in ways that are only partially understood. Events on land, in the sea, and in the air can affect the processes and rates over a very wide area of the earth since this is a single global life system.

Only in recent centuries has the human species exerted more than a trivial impact on biological events. In the century since the industrial revolution, man has brought large areas under control, changed populations, and, eventually, collected and used such large quantities of some materials as to modify parts of the biosphere. Improved agricultural yields and grave pollution problems are both aspects of these accomplishments.

Man is an integral part of the living system, which includes over a million species in the United States. Most of these are considered essential to the well-being of man. Pesticides are now affecting individuals, populations, and communities of natural organisms. Some, especially the persistent insecticidal chemicals such as DDT, have reduced the reproduction and survival of certain nontarget species while causing explosive populations of other organisms. A nontarget species is one that is not purposely being attacked (fig. 16).

Pesticides are dispersed via air, water, and the movements of organisms. The most significant concentrations are found in and near the areas of intensive use. Pesticides, along with reduced favorable habitats and other detrimental environmental factors, have reduced the populations of several wild bird species. Both extensive field data and the results of excellent controlled experiments demonstrate that certain birds, fishes, and insects are especially vulnerable. There are suggestions that pesticides in the environment may adversely affect processes as fundamental to the biosphere as photosynthesis in the oceans. Present evidence would indicate that this is extremely unlikely.

However, the scarcity of information concerning the influences of insecticides on natural animal populations prevents adequate assessment of their total effects. Less than 1% of the wild animal species in the U.S. have been studied in this connection, and very few of these have been subjected to adequate observation. Present methods and programs for determining the influences of pesticides on nontarget organisms are inadequate.

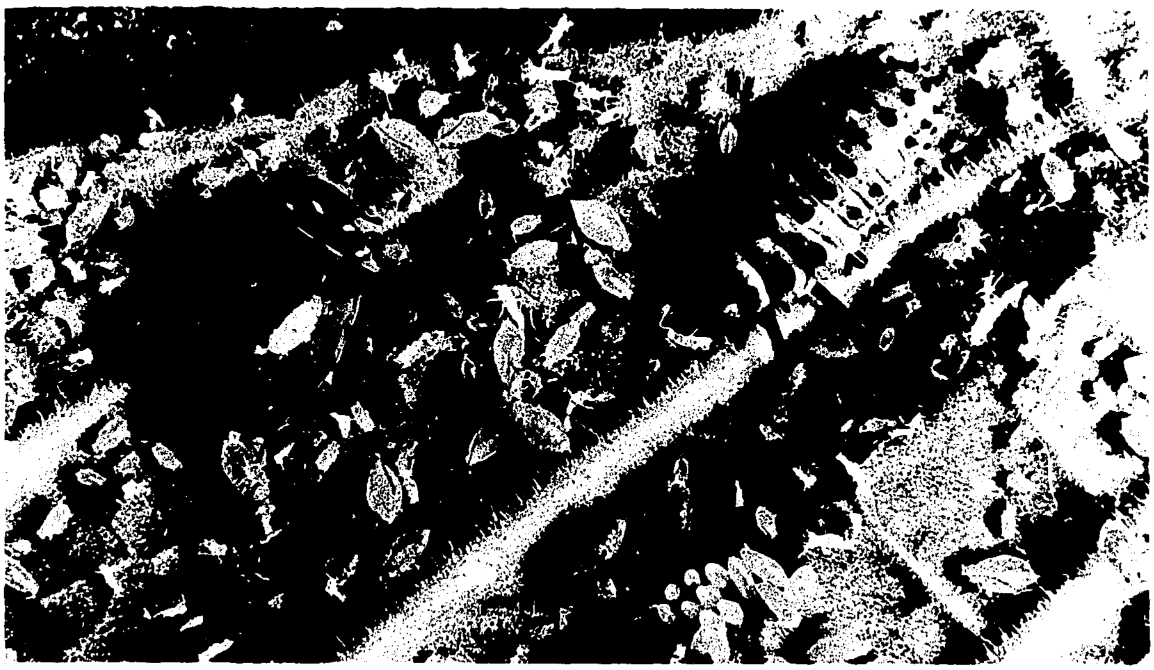

USDA Photo

Fig. 16—Persistent insecticidal chemicals have reduced the reproduction and survival of certain nontarget species such as this adult and larva lady beetle shown here feeding on aphids.

The general nature of the effects of insecticides on nontarget species populations and communities can now be suggested. Although there is usually greater similarity of reaction between closely related species, each species reacts differently to specific pesticides under laboratory conditions. For example, DDT causes egg shell thinning in ducks and falcons but not in pheasants and quail. Pesticides from the air, water, and soil may be concentrated in the bodies of organisms. The concentrating effect is frequently enhanced as one species feeds on another and passes the pesticide from one link to another in the food chain. Hence, predators like some birds and fish may be exposed to levels several thousand times the concentration in the physical environment. Some nontarget organisms can, under highly selective pressure from pesticides, evolve resistance to them. The surviving resistant individuals may pass extremely high concentrations to their predators. In animal communities exposed to certain insecticides, especially those with broad spectra, the number of species is usually reduced and the stability of populations within the community is upset. Often, beneficial species are unintentionally eliminated. Such a reduction in the number of species is frequently followed by outbreaks or population explosions in some of the surviving species, usually those in the lower parts of the food chain. When a vital link low in the food chain is eliminated, many predators and parasites higher in the food chain are often also destroyed.

EFFECTS OF PESTICIDES ON MAN

No human activity is entirely without risk, and this maxim holds for pesticide usage in the human environment just as it does for all other exposure to chemicals. There are difficulties in fully evaluating the risks to human health involved in the use of pesticides. One must not lose sight of the large number of human variables, such as age, sex, race, socioeconomic status, diet, and state of health, all of which can profoundly affect human response to pesticides. As yet, little is known about the effects of these variables in practice. Finally, one must realize that the components of the total environment of man interact in various subtle ways, so that the long-term effects of low-level exposure to one pesticide are greatly influenced by universal concomitant exposure to other pesticides as well as to chemicals such as those in air, water, food, and drugs.

Scientists would like simple clear-cut answers to the questions posed by human exposure to pesticides, but the complexity of the human environmental situation seldom allows such answers to be obtained. Attempts to transfer results of animal experiments to man are also beset with pitfalls. Hence, the greatest care needs to be exercised in drawing conclusions regarding cause-and-effect relationships in human pesticide exposure. The use of modern techniques has made possible the study of absorption, deposition, metabolism, and excretion of some pesticides in man.

Experience derived from animal studies has provided guidance in directing the appropriate procedures to the investigation of the behavior of pesticides in the human body. To date, the most significant information of this sort relates mainly to two organochlorine pesticide groups, namely, DDT and allied compounds as well as the aldrin-dieldrin group. Knowledge of the behavior of these two pesticide groups in the human body is far from complete, but already some important facts have been established. In general, for any constant level of pesticide intake, an equilibrium of pesticide is attained in blood and body fat, despite continuing exposure. The precise concentration when the plateau is established is directly related to the level of exposure but also to other factors. In the case of aldrin-dieldrin, the level in the blood appears to be a reliable measure of exposure. Further, it appears that DDT in blood is directly related to recent exposure while, in contrast, DDE (a degradation product) in blood is a reflection of long-term exposure. Exposure to accidental poisoning by organochlorine pesticides, often causes excitability and nervousness. Some of these compounds may also damage the liver.

The capacity to penetrate intact human skin varies from one compound to another. Within the organochlorine group there is a wide range of potential for acute toxicity: DDT is relatively safe in terms of acute intoxication, while dieldrin and endrin have produced many cases of serious poisoning. Lindane has been implicated in the causation of hemotological disorders. A characteristic of organochlorine poisoning is the difficulty of establishing the correct diagnosis. This is especially true in cases of mild poisoning that result in nonspecific symptoms and signs since, except in the case of dieldrin, there are no established criteria for diagnosis on the basis of blood levels. Specific therapeutic measures do not exist.

Inhibition of cholinesterase enzymes by the organophosphate pesticides appears to be the only important manifestation of acute toxicity produced by this class of compounds. Great variation in acute toxicity from one compound to another characterizes this group, which includes some of the most toxic materials used by man and also the safest. Cholinesterase inhibition results in a well-defined clinical pattern of intoxication that can be diagnosed readily. Specific therapeutic measures are available and, provided they are pressed with sufficient speed and vigor, are highly effective. Skin penetration by organophsophates may be substantial. In view of the toxic potential of these compounds, protection of workers exposed to them is of utmost importance.

Carbamate pesticides are also cholinesterase inhibitors, but measurement of cholinesterase activity is not a reliable guide to their exposure. As with organophosphates, the toxic potential of some members of the carbamate group is very great while the widely used insecticide, carbaryl, is quite safe.

Controlled exposure of human volunteers to pesticides under close medical supervision constitutes the most reliable approach to the evaluation of long-term effects of low levels of pesticide exposure. The difficulties in such studies have inevitably resulted in too few subjects exposed for too short a time. The longest studies on record have lasted less than 4 years. Consequently, the findings, especially when they are negative, are open to question when taken by themselves. It appears, however, that present levels of exposure to DDT among the general population have not produced any observable adverse effects in controlled studies on volunteers.

Other health hazards of pesticides are their possibility of producing inheritable alterations in the genetic material (mutagenesis), adverse effects on reproduction, including malformations in the fetus or newborn infant (teratogenesis), and increasing the incidence of various forms of cancer (carcinogenesis). None of these injurious effects have been shown in humans. The data available relate only to experimental animals. At present, we are uncertain that these results are applicable to man. Nevertheless, the potential to damage our health is indicated by animal studies and indicates cause for concern and careful evaluation. It is prudent to minimize human exposure to substances producing these adverse effects in mammals while additional investigations are undertaken. Assurance of safety to man demands special techniques, not only for extrapolation of animal data to man, but also for evaluation of controlled human exposure. Research in these areas should be expanded with a great sense of urgency (fig. 17).

To sum up, the field of pesticide toxicology exemplifies the absurdity in which 200 million Americans are undergoing lifelong exposure, yet our knowledge of what is happening to them is at best fragmentary and for the most part indirect and inferential. While there is little ground for forebodings of disaster, there is even less for complacency. We should address ourselves to the proper study of the effects on man without delay.

Improvement in the present situation requires:

- Organization of resources for effective continuing action
- Improved registration and review practices
- Clarification and strengthening of laws and regulations
- Action to improve the health of the public
- Initiation of programs to evaluate and provide a system of graded actions for existing contamination or contamination that cannot be controlled at the source
- Research and investigations
- Industrial cooperation

USDA Photo

Fig. 17–All types of analytical tools are used to help determine the effects of pesticides on man.

RESIDUES

It would be ideal if a pesticide could be applied to a plant or soil, remain long enough to control the pest, and then disappear completely before harvest. Unfortunately, this is not usually the case, so regulations are necessary to ensure that pesticide residues are not harmful to humans, animals, crops, or other segments of the environment.

Before a pesticide can be sold in interstate commerce, it must be registered with the EPA. This agency administers the Federal Insecticide, Fungicide, and Rodenticide Act, as amended by the Federal Environmental Pesticide Control Act of 1972, which specifies requirements for registration. One of these requirements is information on the amount of pesticide residue that can be expected on a crop at harvest when directions on the label are followed. The residue may consist not only of the pesticide itself, but also of certain products derived from the pesticide as it breaks down. These products are often referred to as degradation products or metabolites. Generally these products are less toxic than the original pesticide, but some are more toxic. Eventually, most, if not all, of these products are further decomposed to substances that are no longer of any concern to public health. This may require days, months, or sometimes years.

Many factors influence the amount of residue that will remain on a crop after a given time, and a test in only one location is rarely adequate for registration. Occasionally, registration is granted on the basis of such limited testing, but use of the pesticide is generally restricted to the area where the tests are conducted.

Factors related to location that affect residues are principally climate and soil type. There are other factors, not necessarily related to location, that also influence the persistence of pesticide residues. These include nature, formulation, deposition, and growth dilution of the pesticide.

Nature of the Pesticide

Pesticides differ widely in their capacity to persist as residues in plants or soil.

Formulation

Pesticide formulations, i.e., emulsifiable concentrates, wettable powders, flowables, dusts,granules, oil sprays, etc., have quite different properties, often resulting in different amounts of residue at harvest from the same rate of application.

Since formulation can have a marked effect on the activity and persistence of pesticide residues, a label for each formulation must be registered with the EPA. Thus, there are instances where only certain formulations are registered for use on a crop, even though others are available.

Of particular interest at this time is the use of undiluted pesticides in aircraft application. These are commonly referred to as "ultra-low-volume" (ULV) sprays and are defined by the EPA as concentrated or technical liquids applied undiluted at the rate of half a gallon or less per acre. Applicators should not use this low-volume technique with pesticides unless they are registered specifically for this purpose.

Deposition

The amount of pesticide initially retained on a surface is referred to as a deposit. When this deposit disappears with time as a result of weathering and other processes, the remaining chemical is known as a residue. The distinction between the two is primarily when the chemical determination is made. Generally, the larger the deposit, the longer an appreciable residue will persist.

The size of the deposit is governed by many factors, perhaps the more important being dosage, weather at time of application, application equipment, formulation, and plant structure. The probable effects of decreasing dosage or making an application during windy or rainy conditions are rather obvious. However, it is difficult to generalize about the effects of different types of application equipment and formulations.

Plant structure may have a very notable influence on the amount of spray or dust that remains on a plant surface. For example, very little spray liquid adheres to narrow, upright leaves, such as cereals and onions, or to very waxy leaf surfaces. On the other hand, sprays tend to remain on broad-leaved plants, especially those with leaves extending nearly horizontally from the plant stem. Dense foliage interferes with the penetration of sprays and dusts to the inner leaves. Hairy leaves and fruits are more likely to retain dusts than are smooth plant surfaces. Even distribution of deposits can be facilitated with spreaders, stickers, and other surfactants. These and many other examples are reasons why residue data are needed for each crop for which a registration is requested.

Growth Dilution

Pesticide residues are expressed in terms of parts per million(ppm) by weight. A residue of 10 ppm on an apple would correspond to 10 grams of residue per 1 million grams of apples, or 10 pounds of residue per 1 million pounds of apples, etc. It is obvious that when an apple increases in weight after a pesticide is applied, the residue will be diluted. For example, doubling the weight of an apple with 10 ppm residue would reduce the residue to 5 ppm, assuming there was no loss due to other factors. The more rapid the rate of growth, the more rapidly the residue will be reduced. Timing of application with respect to plant growth and maturity is, therefore, an important factor in determining how much residue will remain at harvest.

TOLERANCES

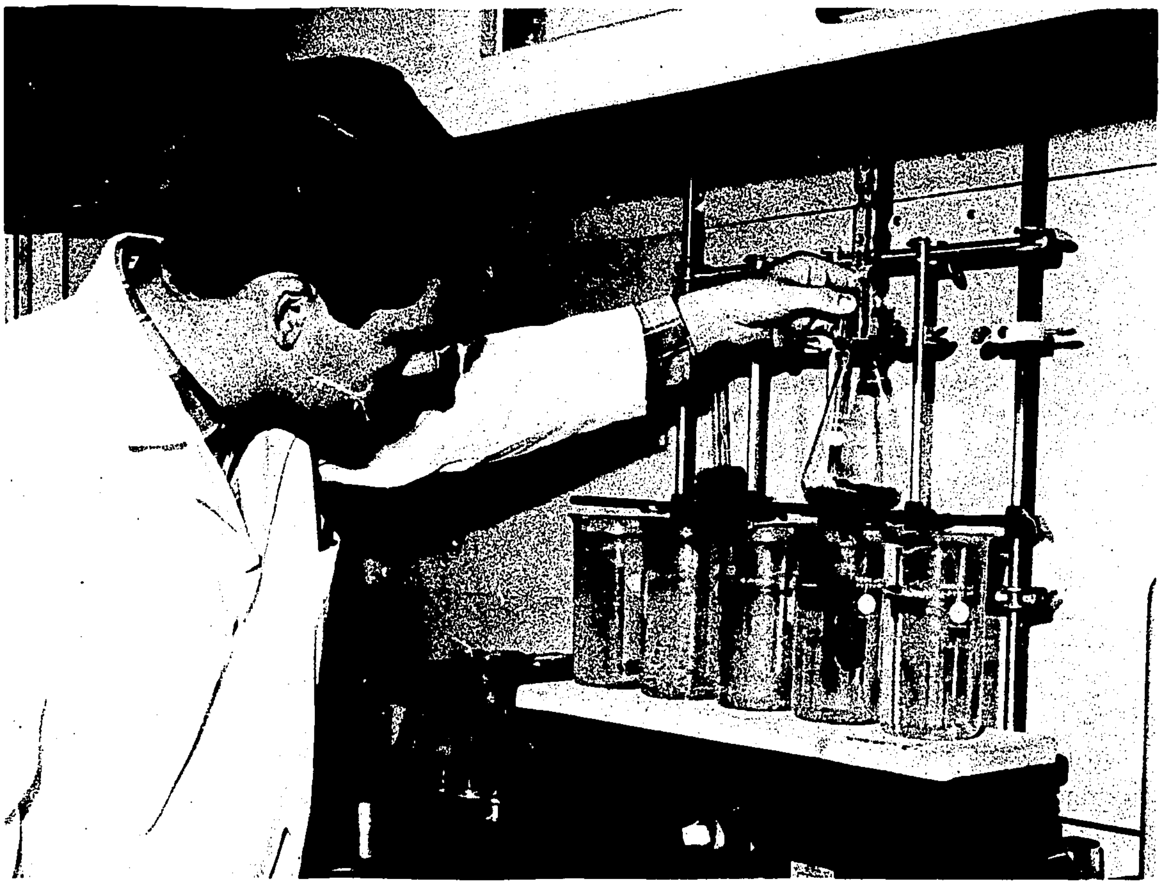
Establishment

A Federal tolerance is the permissible amount of pesticide residue remaining on a commodity being shipped interstate. The EPA establishes these tolerances for pesticide residues on raw agricultural commodities. These tolerances are based on scientific evidence from animal studies provided by the manufacturer that the pesticide used according to instructions is safe. However, before the EPA will set a tolerance, it must have data to show that the pesticide is useful and information on residues resulting from the proposed use. If this information is adequate, EPA reviews the animal studies, which include both short- and long-term feeding of at least two species of animals. The long-term studies are usually conducted for the life span of the rat and for 1 or 2 years in the dog or monkey; in addition, rats are studied to determine if there are any effects on several succeeding generations.

It is assumed that people may be more sensitive than test animals; therefore, the tolerance must be set lower than the amount that produced no effect on the most sensitive test animal. A safety factor of at least 100 to 1 is followed, i.e., if 1 gram per day was determined a safe level for the test animal, no more than 0.01 gram per day would be permitted in human food. No tolerance is allowed for any pesticide that has been shown to cause cancer in animals or man. If a tolerance can be established, it is set at the lowest level that will accomplish the intended purpose, even though it appears that a larger amount would be safe.

No-Residue and Zero-Tolerance Registrations

Formerly, tolerances were not required on food crops if no residue could be detected at harvest. Difficulties were encountered when more sensitive analytical techniques were



USDA Photo

Fig. 18—A laboratory technician purifies and concentrates a citrus peel solution so that only the residue from pesticide treatment remains in the solution.

developed so that residues were found where none were known to exist previously (fig. 18). As a result, the concept of no-residue and zero-tolerance registrations was abandoned. Now, any use that can reasonably be expected to result in small residues in or on food must have a tolerance whether a residue can be detected or not. If the residue is extremely small or nondetectable, a negligible residue tolerance may be established with a less extensive animal feeding study than is required for "regular" tolerances. It must include at least a 90-day feeding study with two species of mammals, and the tolerance must be set so that the human diet will not contain more than 1/200th of the amount that has no effect on the most sensitive animal species tested.

Non-Food-Use Registrations

In certain instances, registrations may be granted without a tolerance, but only when there is virtually no possibility of residues occurring in human food or animal feed. These are referred to as non-food-use registrations.

Exemptions From the Requirement of a Tolerance

In certain instances, pesticides may be exempt from the requirement of a tolerance if it can be shown that there is no hazard to human health when used as directed. Such an exemption may be granted even though there is a possibility of residues on the harvested crop. An example is the use of petroleum solvents used as carriers of other pesticides.

Enforcement

The Food and Drug Administration (FDA) has responsibility for checking food in interstate commerce to determine if pesticide residues exceed tolerances established by the EPA. Excessive residues are illegal, and the contaminated food can be removed from the market. If there is evidence of willful misuse or negligence, the applicator and/or grower may also be penalized.

ALTERNATIVES TO AGRICULTURAL CHEMICALS

Biological Control

Biological control is controlling a pest with the use of any other organism, e.g., a bird, a mammal, an insect, or a disease. One of the oldest and most successful means of insect control is by pitting insects against insects. All insect pests have natural insect enemies that fall into two groups: predators and parasites. These two groups are broadly separated as follows:

Predators

- Usually larger than host insect
- Attack directly and kill host
- Usually attack any number of hosts
- Not dependent on any specific host for survival

Parasites

- Usually smaller than host
- Attack indirectly—lay eggs on host and immature stages slowly devour host
- Generally host specific or with very few hosts
- Quite dependent on specific host for survival

Both groups of insects and other beneficial small animals may be very helpful in reducing pest insect numbers. The value of these beneficial species has been recognized for many years, but extensive collecting of beneficial species to control pest species was begun about 100 years ago. Probably the first real noteworthy introduction of a predator insect for control of a specific pest species was the introduction of the Vedalia lady beetle, *Rodolia cardinalis*. This predacious lady beetle was introduced into California from Australia to control the cottony cushion scale, a serious pest of citrus in that State. The cost of this venture in 1888 was $2000. It literally saved the California citrus industry and continues to control this serious scale pest.

Several predacious insects and mites give good control of many aphid, leafhopper, and true bug pests, as well as a miscellany of other insect and mite pests. Probably the most noteworthy insect predators in Washington fields, orchards, and gardens are the lady beetles, pirate bugs, big-eyed bugs, assassin bugs, green and brown lacewing larvae, syrphid fly larvae, and common garden spiders. A large number of wasps and flies are also effective predators in some areas.

The most notable success with biological control in Washington State is the development of the use of an orchard predator mite, *Metaseilus occidentalis*, for control of the McDaniel spider mite, *Tetranychus mcdanielei.* This work was accomplished by Dr. Stanley Hoyt, entomologist at the Washington State University Tree Fruit Research Center at Wenatchee. Dr. Hoyt discovered that this predator mite could give excellent control of destructive mites if sprays were selected and applied to avoid damage to beneficial mites. Many beneficial insects and predacious mites may be protected in this way if farmers, homeowners, chemical salesmen, dealers, and fieldmen promote only those chemicals that cause less injury to beneficial insects and only use them when absolutely needed.

Many beneficial parasitic wasps and flies are present in our State. A notable example of the use of these tiny wasps is in controlling the pea aphid on peas and alfalfa in south-central Washington. This has been done by USDA entomologists from the Yakima Research Station. These tiny wasps often reduce aphids to numbers that generally no longer require chemical control. Parasitic insects are also particularly effective in controlling the caterpillars of many destructive moth and butterfly species.

Cultural Control

The principle of this type of control depends on the proper manipulation of the pest species' environment. It may mean the elimination of intermediate host plants that act to hold over certain stages of the insect pest. It could mean a change in crops or crop handling to eliminate one or more of the pest insect's life cycle.

Cultural control may be developed using several methods. The method for individual insects will vary depending on life cycle and stage of development. Methods used in cultural control are sanitation; tillage; rotations; trap crops; and land, livestock, and tree management.

Sanitation

Sanitation involves the removal of refuse and debris that may harbor destructive insects. This includes the cleaning up of field and orchard borders and wildlands that support high levels of pest species and quick disposal of crop wastes that harbor pests.

Tillage

Tillage refers to the breaking up of the ground or sod by various mechanical means such as disks, harrows, and deep plows to either destroy the destructive insect or to remove his sources of habitation.

Rotation

Rotation consists of changing crops in an area to eliminate the chances of the pest species surviving year after year on the same crop in the same area.

Trap Crops

Trap crops are small areas of highly attractive crops used as bait to attract certain destructive pests. After the pest species moves into these attractive areas, they are sprayed or destroyed as quickly as possible, thus reducing a large number of the injurious insect species in the area.

Land, Livestock, and Tree Management

Many cultural programs fall into the land, livestock, and tree management category. Stripcropping may either increase or decrease pest insect activity. In wheat and fallow areas, it has increased the amount of wheat stem sawfly in the midwest, whereas, with alfalfa in California. it has helped in controlling the spotted alfalfa aphid. By chemically treating or cutting only alternate areas, the remaining land harbors many beneficial insects that later attack the pest species in both the sprayed and unsprayed areas.

Changing planting times to avoid certain life stages of destructive insect pests is another management program often used. Removal of attractive alternate hosts, changing planting distances, and changing harvest timing and procedures are also often used to control or reduce outbreaks of destructive insect pests.

Physical and Mechanical Control

Physical and mechanical insect control methods are the oldest and possibly the most primitive of all insect control practices. Although some insects may survive extreme temperature changes, others may not. Extreme sources of heat, such as fire, often greatly reduce insect numbers of many species. Prolonged high temperatures from the sun or other means of obtaining warmer-than-average conditions may reduce populations of some species. Extremely cold conditions may also greatly reduce pest species. The corn earworm is entirely destroyed with subzero weather when the ground is bare. Here in Washington State we see greatly retarded insect activity of some species following a damp cold spring.

High humidity can be a big factor in insect buildup or decline because it promotes diseases in some insects and supplies the necessary moisture for other insects' survival. High moisture in stored grain is particularly favorable for insect development.

The use of various types of mechanical traps such as light traps that attract insects to their final doom is another form of control.

Feeding Deterrents and Hormones

The ultimate goal in insect pest control is the protection of the crop or other commodity from damage. Ordinarily this is accomplished or attempted by eliminating the pest. This end could be accomplished by excluding or deterring the pest from its food.

Feeding deterrents accomplish this by preventing feeding, thus eliminating the damage rather than the pest. A synthetic compound, 4-(dimethyltriazeno)-acetanilide, is a very effective deterrent when used against the cabbage looper. Corn earworms would not feed on corn leaves or silk treated with this chemical. Paper bags treated with the chemical prevented several insect species from attacking stored grains and seeds.

Hormones—chemicals produced naturally by plants and animals—regulate growth and other physiological processes. In insects they control metamorphosis. Insects require proper nutrients and a good environment to progress properly through their various life stages and complete their metamorphosis. Insect hormones must be regulated to very exact levels if the insect is to grow at an ideal rate. If these hormones are in great excess or almost absent, the insect has retarded growth or it may never reach maturity. An insect that does not mature cannot propagate, so the population declines. By adding certain hormones, particularly the so-called juvenile hormones, the life cycles of insects are retarded preventing further development and reproduction.

Microbial Control

Like man and animals, insects also are affected by diseases. Fortunately, the microorganisms that attack insects are not injurious to man and other vertebrates. Some of these diseases are injurious only to specific species or small groups of insects. Because of the great fear of the possible spread of viruses and the public and governmental concern for virus movement from insects to other animals, the use of micro-organisms in insect control has moved rather slowly to date.

A number of bacterial, fungal, and viral diseases kill many types of insects. Several problems, in addition to the potential health hazards of viruses, have been encountered in using microbial control agents. The most serious of these are: (1) variability of the effectiveness of the disease organism; (2) method of formulation to retain effectiveness; (3) stability of formulation; (4) need for proper timing of application of the micro-organism with respect to the insect's life cycle; (5) the effects of weather on both microbial activity and insect activity; and (6) difficulty in obtaining registrations.

This means of pest control possesses real merit but has many hurdles to leap before it can be considered a standard insect control procedure.

Resistant Plants and Animals

The use of resistant plants and animals dates back to the earliest days in insect control in the U.S. Resistance of wheat to the Hessian fly were first mentioned in 1785. The study of animal resistance to insects and similar pests has only been noted in very recent times.

The control of pests through the use of resistant plants or animals is not truly a control method but, rather, a type of prevention. Resistance is made up of varying degrees of one or more components: preference, nonpreference, antibiosis, and tolerance. Preference and nonpreference refer to characteristics within hosts that cause insects to either avoid or become attracted to them. This may be due to mechanical factors, such as hairiness or slickness of leaf, or to chemical factors that may repel or attract insects. Antibiosis consists of the inherent characteristics (usually chemical) of the host that weaken or destroy the attacking insect. Tolerance is the ability of the host to withstand the onslaught of the pest.

It enables the plant or animal to quickly repair damage or quickly return to normal after being under attack.

Insect resistance has recently been under study, and a large number of successful grain and sorghum strains have been developed. Grains and forages are particularly suitable for resistance as they are often produced annually, and small losses may be tolerated to a greater degree than in some of the high-income fruit and vegetable crops.

Control Through Sterilization

Sexual sterilization of insects was established as a practical means of control in the mid-1950s when the screwworm fly was eradicated from the West Indian island of Curacao and from the southeastern portion of its range in the U.S. by the release of flies sterilized by exposure of the pupae to gamma radiation. Studies since this successful program have shown both good and bad results.

At present, large-scale studies on the possible use of sterile codling moths for control of this pest in the State of Washington and the province of British Columbia, Canada are well underway. Sterilization programs require rather large outlays of money, however, to be developed properly. Large rearing facilities are needed to obtain insects for release. Holding facilities, sterilization machinery, and application equipment are all quite expensive and are definitely possible deterrents to this type of program. Benefits are many, however, as no chemical or foreign material is released to contaminate the environment.

Regulatory Control

The old saying, "An ounce of prevention is worth a pound of cure," is the basis of regulatory entomology. Preventing the entry and establishment of foreign plant and animal pests in our country, State, or area is the core of any regulatory program.

Efficient regulatory programs hinge on decisions involving such questions as: What constitutes a serious pest? Can a pest of the type to be regulated actually be kept from moving from one area to another? Is it economically sound to regulate this pest? Are laws on the books in your area to carry out a regulatory program? Are manpower and equipment available to inspect and intercept the pest or its host material? Can the shipment of plants or animals that serve as hosts for the pest be regulated? If all the questions can be answered with a positive "yes," then you can consider a regulatory program in keeping pests from coming into a new area.

Probably the greatest value of a well-planned regulatory program is its ability to slow down the movement of insect pests until studies and research can develop adequate control measures.

Some of these same control devices can be used on other pests. Most concern so far has been with insecticides because they are usually the most toxic.

SOCIOECONOMIC EVALUATION

Agricultural chemicals are extremely important in agricultural production. They influence the quality and quantity as well as efficiency of production of agricultural products. As economic pressure is put on the producer to become more efficient he usually responds by using more agricultural chemicals.

Not only are agricultural chemicals important socially and economically, as they affect the producer and consumer, but the chemical industry itself is important as it produces over a billion dollars worth of materials per year.

The social and economic implications may change considerably as demands for agricultural products increase. This increased demand will become more acute as the population and the need for food increases.

THE FUTURE OF AGRICULTURAL CHEMICALS

The Environmental Protection Agency now has the responsibility for registering pesticides. They are tightening restrictions on registrations in many ways, especially to more specific uses of formulations.

Although new technologies and exciting leads toward nonchemical methods of pest control are seen on the horizon, most experts feel these are a long way off. Therefore, we will be relying on chemicals to produce and protect most of our agricultural production for the foreseeable future.

We will develop better methods and have more experts available to determine if and when chemicals are needed, what chemical should be used, and how the material should be applied. Through such an approach, pesticide control will be tailormade for each situation.

It will become even more necessary to have various disciplines, such as scientists, economists, and social scientists, contribute to solving the problems involved with the use of pesticides and other agricultural chemicals. Education will be important in informing people about the necessity of agricultural chemicals and their proper use.

As the population of the world increases, there is little doubt that there will be a greater demand for agricultural chemicals and a greater demand that they be used to minimize environmental contamination.

Much of the effort in the area of pesticides will center for some time on interpretation and implementation of the Federal Environmental Pesticide Control Act of 1972.

RADIATION

More and more, people are realizing that radiation is a hazardous byproduct of our modern technology. The exposure of larger segments of the world's population—particularly in the industrialized nations—to a variety of low-level, manmade radiation sources is increasing. The increase, both in the number of sources and in the number of people exposed, raises questions about the magnitude and nature of the hazard to human health of ionizing radiation. This questioning has occurred both among the general population and within the scientific community and focuses on the adequacy of existing radiation protection standards.

Sources of Radiation

Natural (Background) Radiation

The earth's natural background of radiation arises from two general sources. One is cosmic radiation that enters the earth's atmosphere. The dose received at any point on earth from cosmic sources varies with altitude and latitude. The other major source of natural background radiation is radioactive isotopes found in water and in mineral deposits. The total radiation from natural sources can contribute an average individual yearly dose of about 125 millirems.

Manmade Sources of Radiation

Manmade sources of radiation include X-rays, radioactive materials, and electronic devices in the home, office, and industry. Medical uses of radiation now represent the largest single source of manmade radiation—about 94% or roughly 30% of all radiation sources to which the average person is exposed. An increasing awareness of this fact and its potential hazard has led to some reduction in medical uses of radiation in recent years and to improvements in the techniques of their use.

Effects of Radiation

It is known that high levels of radiation adversely affect human health in a number of ways. Various forms of cancer in humans and experimental animals have been associated with relatively high doses of radiation. It has been demonstrated in leukemia and other cancers that, at doses above approximately 100 rems, a proportional relation exists between the size of the dose and the incidence of the disease. (The unit "rem" stands for "roentgen equivalent man" and reflects the amount of radiation absorbed in human tissues and also the quality of the type of radiation.)

It is much more difficult to assess the potential biological effects of low-level radiation. Measurements of effects at very low doses (comparable to those that might be expected in the natural environment) are technically difficult or impossible. One reason is that man's biological responses to ionizing radiation depend on a myriad of factors—type, amount, and rate of radiation received; whether it comes from external sources; and whether the whole body or particular organs are exposed.

One of the major potential effects of low-level radiation is that human genes may be damaged or altered. The risk of genetic damage lies behind most of the recommended standards for radiation exposure. There is a natural mutation rate among humans that is believed to be caused, at least in part, by natural background radiation. From this, it is reasoned that any manmade sources of radiation that augment natural background radiation will similarly be responsible for a proportionate statistical increase in the number of genes affected. The risk of such an increase argues most strongly for conservative radiation exposure practices.

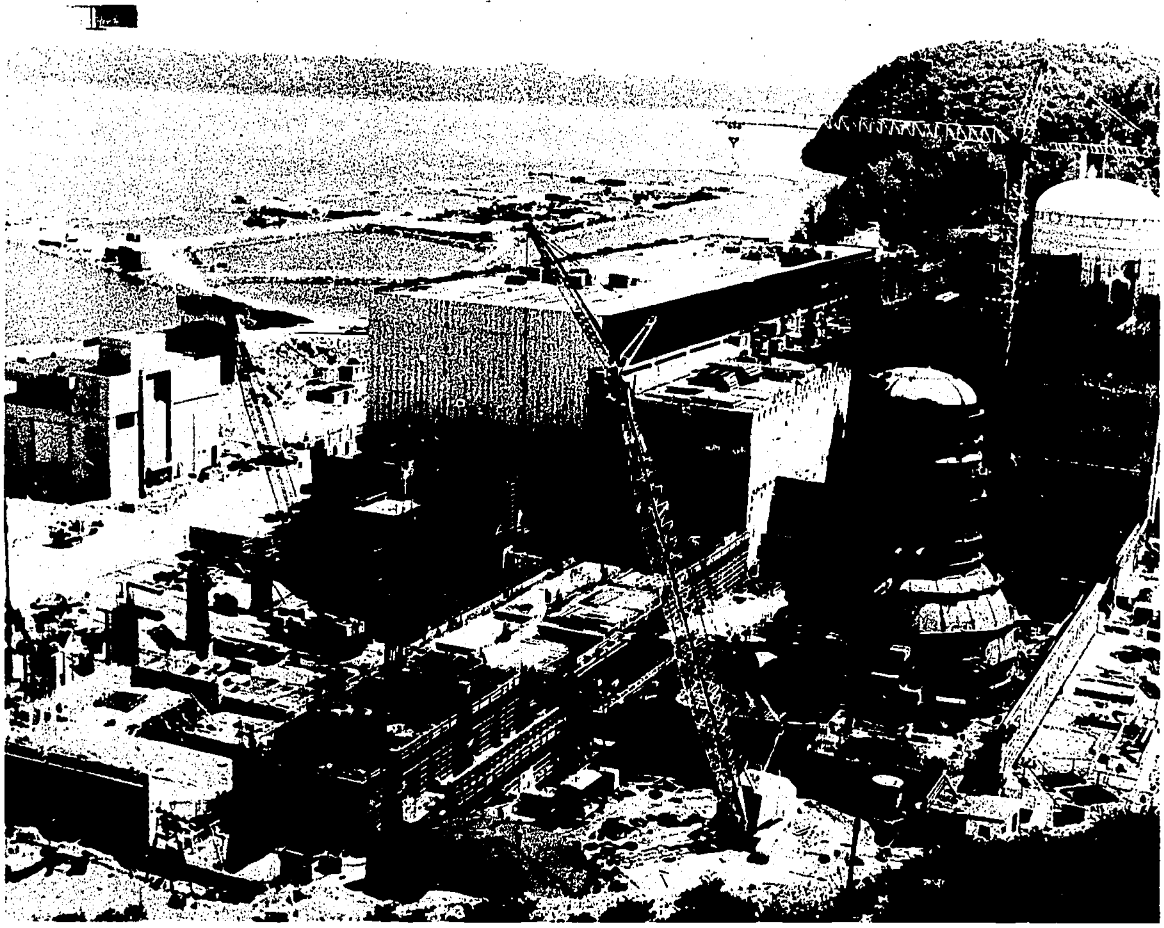


Fig. 19—The new Peach Bottom Nuclear Generator Plant, Peach Bottom, Pennsylvania will produce 1 million kilowatts of electricity; the reactor itself weighs 700 tons and is 75 feet high.

Safety Record of Reactors

A nuclear reactor cannot explode like an atomic bomb. The most serious safety hazard it poses is that excessive heating could melt the core and spill large quantities of radioactive materials into the environment. To make this possibility extremely remote, an extensive safety program has been developed.

Since the beginning of the nuclear energy program in 1943, there has been only one reactor accident in the United States involving fatal injuries. In the commercial nuclear power program, no radiation injuries or deaths have resulted from the operation of licensed nuclear powerplants in the United States (fig. 19). There have been other deaths from high-level radiation not associated with reactors.

Radioactive Waste Storage and Disposal

The management of radioactive waste material in the nuclear energy industry can be put into two general categories. The first is the treatment and disposal of materials with low levels of radioactivity. These materials are the gaseous, liquid, and solid wastes from reactors and other nuclear facilities. The second category involves the treatment and permanent storage of much smaller volumes of wastes with high levels of radioactivity. These high-level wastes are byproducts of the reprocessing of used fuel elements from nuclear reactors. Their disposal will become more and more of a problem, particularly as their volume increases with society's expanded uses of radiation sources in the future.

Standards for Protection Against Ionizing Radiation

The formal procedures and scientific bases for developing and establishing standards for protection against ionizing radiation are the most comprehensive of any applied to environmental stresses. However, the effects of radiation on man are not fully understood, and there remains room for disagreement over the adequacy of current standards.

Radiation exposure standards are re-examined as knowledge expands. Although the biological effects on man of low-level exposures have not been precisely quantified, current standards use a conservative extrapolation of measured data at high exposures to set radiation standards of low levels. Further, as advised by the Federal Radiation Council, efforts are made to keep exposures as low as practicable. Experience has shown that actual exposures are small fractions of radiation protection standards. However, as the number of radiation sources grows (for example, nuclear powerplants), increasing attention will have to be paid to the apportionment of radiation doses from these sources.

Effects of Radioactive Contaminants on Agriculture

Tobacco leaves are reported to contain the peculiar capacity to accumulate polonium-210 at an appreciable level. This level varies with location, culture, type of tobacco, and curing methods. Polonium-210 volatilizes at the temperature of tobacco combustion and may be inhaled into the lungs by smokers. Thus, it has been suspected of being one of the factors causing lung cancer that is associated with smoking. This potential effect of polonium-210 in tobacco is still a debated question. Many scientists consider its level to be too low in tobacco to constitute a hazard to smokers.

Radioactive contaminants in farm products may cause economic losses to farmers. During the spring of 1966, milk was confiscated on a dairy in Nevada because of an unduly high level of iodine-131 in the area as a result of accidental venting during and following an underground weapons test. Dairymen in central Minnesota considered using stored feed instead of pastures during the summer of 1962, when worldwide fallout from nuclear testing reached its highest level. The estimated direct cost of this action in one small area would have been $9000 a day.

GLOSSARY

Most of these selected terms were taken from the *Washington Pest Control Handbook.*

Absorption—Penetration of a substance from the surface to below the surface.

Active Ingredient—An ingredient that provides stimulating or killing action. In pesticide use, this generally is equivalent to the amount of technical material in a formulation.

Acute—Poisoning by a single dosage or dosages applied to animals over a short period.

Acute Oral LD_{50}—In toxicity studies, it is the dosage required to kill 50% of the test animals when given a single dosage orally. The dose is expressed by the weight of the chemical per unit of body weight, example is milligrams of toxicant per kilogram of body weight of the test animal. In this unit, LD_{50} toxicities are expressed as oral toxicities to rats unless otherwise stated.

Adhesive—A substance that will cause a spray material to stick to the sprayed surface; a sticking agent.

Adjuvants—Combined with spray materials to act as wetting or spreading agents, stickers, penetrants, emulsifiers, etc., aiding in the physical characteristics of the toxic materials.

Adsorption—Adherence of a substance to a surface.

Aerosol—A colloidal suspension of solids or liquids in air.

Antidote—A practical immediate treatment including first aid in case of poisoning.

Anticoagulants—A substance that prevents normal blood clotting. A poisoned animal bleeds internally causing death. Warfarin is an example.

Attractant—Any substance that lures insects, rodents, or other pests to selected locations where they may then be captured or destroyed.

Avicide—Chemicals that control bird populations.

Bacteria—Microscopic one-celled non-chlorophyll-containing plants.

Bactericides—Chemicals that kill or inhibit growth of bacteria (disinfectants).

Bait—An edible material that is attractive to the pest and normally contains a pesticide, unless used as a prebait.

Band or Row Application—An application to a continuous restricted area such as in, on, or along a crop row, rather than over the entire field area (see broadcast).

Band Treatment—A treated strip extending a few inches on each side of the crop row.

Biological Control—Controlling a pest by natural enemies that may already occur in the area or be introduced.

Broadcast Application—An application of a pesticide over an entire area or field rather than only on rows, beds, middles, or individual plants.

Carbamate–A compound derived from carbamic acid, examples are carbaryl (Sevin) and ferbam.

Carrier–The liquid or solid material added to an active ingredient to facilitate its preparation, storage, shipment, or use in the field.

Carcinogen–Any substance that produces cancer.

Chlorinated Hydrocarbon–A compound containing chlorine, hydrogen, and carbon; an example is DDT.

Chronic Poisoning–Resulting from long periods of exposure to a chemical.

Compatible–Two or more compounds or products are said to be compatible when they can be mixed without detrimentally affecting their performance.

Concentrate–Opposite of dilute; usually concentrated formulations are diluted with water, inert dust, or oil before use.

Concentration–Refers to the amount of active material in a given weight or volume of a mixture. Recommendations and specifications for concentration of agricultural chemicals are frequently given as pounds per unit volume of mixture.

Contact Herbicide–One that kills primarily by contact with plant tissue rather than as a result of translocation. Only that portion of a plant contacted is directly affected.

Contact Insecticide–A compound that causes the death of an insect when it touches its external parts. It doesn't need to be ingested to be effective.

Contaminate To alter or to render a material unfit for a specified use by the introduction of a foreign substance.

Deflocculating Agent–A substance that prevents rapid precipitation of solids in the liquid in a spray tank.

Defoliant–A material that causes the leaves to fall from plants.

Degradability–The ability of a chemical to decompose or break down into less complex compounds or elements.

Dermal Toxicity–Toxicity of a compound absorbed through the skin of animals to produce toxic symptoms.

Desiccant–A drying agent; plant foliage usually is killed by contact action and often seed moisture is reduced, which aids harvest.

Detergent–Any material normally used as a cleansing agent; may be used as a wetting agent due to its ability to reduce the surface tension of water droplets.

Diluent–Any liquid or solid material used to dilute an active ingredient in a formulation.

Dispersing Agent–A substance that reduces the cohesion between like particles (a spreader).

Dissolve–Usually refers to transforming solids into solutions; the breaking apart of solids in contact with liquids.

Drift—The movement of airborne particles from the intended contact area to other areas.

Emulsion—A mixture in which one liquid is suspended as minute globules in another liquid. Examples are butterfat globules in milk or oil in water.

Formulation—A mixture of an active pesticide chemical with carriers, diluents, or other materials, usually to facilitate handling.

Fungicide—A compound used to destroy or inhibit fungi.

Fumigant—Chemicals, usually in the form of volatile liquids or gases, used to kill insects, nematodes, fungi, or bacteria in an enclosure of some kind or restricted to a zone below the soil surface.

Granules—A type of formulation in which the active ingredient is usually mixed and pressed with an inert carrier forming a small pellet.

Growth Regulator—Chemicals that, when applied in small amounts to leaves, stems, or roots, alter the growth and behavior of a plant.

Herbicide—A phytotoxic chemical used for killing or inhibiting (stunting) the normal development of a plant.

Hormone—A substance occurring naturally in plants or animals that controls growth or other physiological processes. Also used with reference to certain manmade, synthetic chemicals that regulate growth activity.

Humidity—Refers to moisture or dampness in the air. Weed killers are often comparatively more effective under moderately humid conditions. In areas or at times when humidity is very low, high herbicidal rates or high volumes of carrier may be required because sprays dry more quickly and absorption is poor.

Hydrocarbons—Compounds that contain carbon and hydrogen only.

Inert Ingredient—Any ingredient added to a formulation for other than its pesticidal action.

Inorganic Compound—Those compounds lacking carbon, e.g., sodium arsenite.

Insecticide—Technically, substances that kill insects. In general use, the term is broader to include attractants, repellents, and other chemicals that regulate insect population.

Integrated Control—Using multiple approaches to pest control. When pesticides are required, they should exert the least adverse effects on the pests' natural enemies.

Label—All written, printed, or graphic matter on or attached to a pesticide or the immediate container, as required by law.

Nematocides—Substances that control nematodes.

Nematodes—Roundworms, especially microscopic forms that cause crop damage, generally found in the soil feeding on plant root systems. Certain species parasitize man and animals.

Nonselective Herbicide—Formulations of herbicides that destroy or prevent plant life in general without regard to species.

Nutrient (Plant)—A chemical element taken into the plant that is essential to its development.

Oils—Usually refers to aromatic or paraffinic oils used as diluents in formulating products as carriers for herbicides or for direct use; also used alone for control of insects and mites.

Oral Toxicity—Toxicity of a compound when it is ingested.

Organic Compounds—Chemical compounds with molecules made up of several carbon atoms.

Organophosphate—An organic compound containing phosphorus, e.g., malathion.

Parasite—An organism that lives in or on the body of another organism and obtains nourishment from it.

Pathogen—The infective agent causing a disease, e.g., fungus, bacterium, or virus.

Pesticide—Any substance or mixture of substances intended for controlling insects, rodents, fungi, weeds, and other forms of plants or animal life that are considered to be pests.

Pesticide Tolerance—The amount of pesticide residue that may legally remain in or on a food crop. Federal residue tolerances are established by the Environmental Protection Agency.

Phytotoxic—Poisonous or injurious to plants.

Postemergence Treatment—Treatment made after crop plants emerge from above the soil.

Pre-emergence Treatment—Treatment made after a crop is planted but before it emerges; generally a weed control procedure.

(1) Contact pre-emergence: An application made after weed emergence but before crop emerges.
(2) Residual pre-emergence: An application that is made before crop emerges and kills weeds as the seeds germinate or as the seedling emerges, either before or after the crop is emerged.

Preplanting Treatment—Treatment made before the crop is planted.

Rate or Dosage—These terms are synonymous. "Rate" is preferred. Rate usually refers to the amount of active ingredient material applied to a unit area regardless of percentage of chemical in the carrier. Example: 1 pound 2,4-D (active ingredient) per acre.

Registered—Pesticides that have bee approved for use by the Environmental Protection Agency or by the State Department of Agriculture.

Repellent—A compound that is annoying to a certain organism, causing it to avoid the area in which this compound is placed.

Residual—To continue to kill or have activity against all or specific life forms.

Residue—That amount of pesticide that is on or in the crop at the time an analysis is made.

Residue Tolerance—The amount of pesticide residue that may legally remain in or on a food crop.

Resistance—The ability of an organism to suppress or retard the injurious effects of a pesticide.

Rodenticide—A compound used to control rodents and similar small mammals. Legally, the term is much broader to include large vertebrates.

Selective Herbicide—One that is more toxic to some species of plants than others. Thus, weeds may often be controlled without significant damage to the crop by selective herbicidal action.

Sensitivity—Susceptible to effects of toxicant at low dosage; not capable of withstanding effects; for example, many broad-leaved plants are sensitive to 2,4-D.

Silvicide—A herbicide used to control woody shrubs and trees.

Solution—Should be used only to describe a formulation in which the ingredients are in the molecular state, for example, DDT dissolved in the solvent, kerosene.

Slurry—A thick suspension of a finely divided solid in a liquid.

Soil Persistence—Refers to the length of time that a herbicide applied to or in the soil prevents the establishment or growth of plants or the period an insecticide will continue to control soil insects.

Soil Sterilant—A soil-applied herbicide that prevents the establishment or growth of plants. Sterilization may be temporary or long terms.

Solubility—The amount of a substance that will dissolve in a given amount of liquid substance.

Solvent—A liquid that will dissolve a substance forming a true solution (liquid in molecular dispersion).

Spot Treatment—An application of a pesticide to a localized or restricted area as differentiated from an overall (broadcast) or continuous strip (band).

Spreading Agent—A substance used to improve the wetting, spreading, or possibly the adhesive properties of a spray.

Sterilant—A chemical used to render the soil barren of all plant growth for a certain length of time.

Stomach Poison—Compounds that kill organisms when they are eaten and absorbed through the alimentary tract.

Surfactant—A material used in formulations to impart emulsifiability, spreading, wetting, dispersibility, or other surface-modifying properties.

Suspension—Particulate matter in a liquid as contrasted to a true solution, e.g., diuron or simazine wettable powders in water and slurries.

Synergism—A cooperative action of different chemicals so that their total activity, in this case control effectiveness, is greater than the sum of their individual effects.

Systemic—Any chemical that, when absorbed into one part of an organism, becomes distributed throughout, for example, Systox.

Teratogenesis—Structural abnormalities of prenatal origin, present at birth, or manifested shortly thereafter.

Therapeutants—Remedies for disease; drugs.

Tolerant—Capable of withstanding effect; for example, grasses are tolerant of 2,4-D to the extent that it can be used selectively to control broad-leaved weeds.

Toxic—Poisonous or injurious to animals and plants through contact or systemic action.

Toxicity—Degree to which something is poisonous.

Translocation—Transfer of food or other materials, such as 2,4-D, from one part of a plant to another.

Vector—An organism, like an insect, that transmits a pathogen.

Virus—A submicroscopic pathogen that requires living cells for growth and is capable of causing disease in plants or animals. Plant viruses are often spread by insects.

Volatile—A compound is said to be volatile when it evaporates or is vaporized (changes from a liquid or solid to a gas) at ordinary temperatures on exposure to air.

Wettable Powder—A power that will readily form a suspension in water.

Wetting Agent—A compound that, when added to a spray tank, causes the spray droplets to spread and more thoroughly wet the surface.

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Caution

If pesticides are handled or applied improperly, or if unused portions are disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, honey bees, and other pollinating insects, fish, and wildlife, and they may contaminate water supplies. Use pesticides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.