PESTICIDE APPLICATION AND SAFETY TRAINING FOR APPLICATORS OF PUBLIC HEALTH PESTICIDES

California Department of Public Health
Vector Control Technician Certification
Training Manual
Category A

PESTICIDE APPLICATION AND SAFETY TRAINING FOR APPLICATORS OF PUBLIC HEALTH PESTICIDES

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Information on certification examination for public health pesticide applicators may be obtained from the California Department of Public Health, Vector-Borne Disease Section, 1616 Capitol Avenue, MS7307, P.O. Box 997377, Sacramento, CA 95899-7377; (916) 552-9730 (http://www.cdph.ca.gov/certlic/occupations/Pages/VectorControlTechnicianProgram.aspx).

Information concerning the laws and regulations pertaining to pest control, pesticide application, and pesticide safety may be obtained from the California Department of Pesticide Regulation, 1001 I Street, P.O. Box 4015, Sacramento, California 95812-4012 (http://www.cdpr.ca.gov/docs/license/liccert.htm).

CONTENTS

INTRODUCTION

Pesticides are chemical substances that are used to kill, repel, or control pests of all kinds. As used in this manual, **pests** refer to arthropods that are of direct public health importance, and vegetation, especially **weeds,** that are of secondary importance because they can contribute to increased production of arthropod pests. Pests covered in this manual also include **vertebrate** animals, especially **rodents**, that are of public health significance. Pesticides used to control **insects** are called *insecticides*, those used to control vegetation *herbicides*, and those used to control rodents, *rodenticides*. Arthropod pests that transmit **organisms** that result in infectious diseases in humans and other vertebrate animals are known as **vectors**.

For legal and regulatory purposes, a **vector** is more broadly defined in the California Health and Safety Code (Section 2002(k)) as: "any animal capable of transmitting the causative agent of human disease or capable of producing human discomfort or injury, including but not limited to, mosquitoes, flies, **mites**, **ticks**, other arthropods, and rodents and other vertebrates."

Chemical pesticides have played a key role in protecting California citizens from harmful arthropods and other pests for nearly a century. Some of the earliest pesticides were those used for mosquito abatement. These included **formulation**s of petroleum and other naturally occurring materials such as sulfur and arsenic. **Weed control** done to modify habitats of mosquito **larvae** was done either with materials such as iron sulfate or copper nitrate, or by mechanical means. Later, plant-derived pesticides such as rotenone and pyrethrum were developed as pesticides used to kill mosquitoes and flies. It was not until the time of World War II that synthetic pesticides began to be used widely for pest control, including the highly effective, **persistent**, and inexpensive chemical DDT. This chemical was found to be effective in controlling a wide variety of medically-important arthropods, including mosquitoes, flies, fleas, lice, and ticks. For about 20 years following World War II many different synthetic pesticides were developed, and for a time, mosquito and vector control agencies placed major emphasis on pesticides for their programs.

In parallel with development of new public health pesticides a series of significant changes in the use, development, and government regulation of pesticides occurred. Some of the factors causing these changes included the development of **physiological** resistance to certain pesticides by pests, improvements in pesticide dispersal equipment, and a realization that certain pesticides could have harmful effects on humans and on the environment, especially if used improperly.

Federal regulation of pesticides has existed almost as long as their use for vector control. President Taft signed the Federal **Insecticide** Act in 1910. The basic law controlling pesticides today is the Federal Insecticide, **Fungicide**, and Rodenticide Act (**FIFRA**). It was signed into law in 1947 and established the requirement for registration of pesticides by the US Department of Agriculture. FIFRA has been amended many times since then. In 1970 regulation of pesticides passed to the newly established US Environmental Protection Agency (**EPA**). In 1972, a major amendment of FIFRA occurred, followed in 1988 by the so-called “FIFRA-lite”, which required re-registration of all pesticides. Currently, EPA has authority for interpretation and enforcement of pesticide laws, including registrations. The US Food and Drug Administration has the authority to enforce **pesticide**

tolerances on food and raw agricultural commodities.

The 1972 version of FIFRA established two categories of pesticides: **general use** (available for public use), and **restricted use** (available for use by **certified applicators** only). The general use category has since been changed to the **unclassified** category, with the same definition. FIFRA delegates responsibility for certification of **restricted use pesticide** applicators to the individual states, and in California, the Department of Public Health certifies government agency employees who apply restricted use public health pesticides. Considerable training and testing is required for certification. It should be noted not all public health pesticides are restricted use, by EPA definition. In fact most today are not. Yet the California Department of Public Health (DPH) requires certification for any government agency employee that handles or applies all public health pesticides (HSC 106925).

Under current law, all pesticides must undergo thorough testing for efficacy, safety and **toxicity** as a basis for registration. Further, all pesticide formulations must be clearly and completely **labeled** as a condition of their sale. The FIFRA laws covering the requirements for registration and are administered in California by the California Environmental Protection Agency, Department of Pesticide Regulation (DPR). DPR maintains direct oversight of pesticide registration and use-reporting, generally working through local County Agricultural Commissioners. California, and all other states, can and do further regulate the sale, use, and possession of pesticides via a state pesticide registration process that mirrors the federal process.

In spite of the many changes relating to pesticide use seen over the past half-century, pesticides remain an essential part of the arsenal available for the control of public health pests. The modern arsenal includes other control approaches, such as ecologically-sound habitat management, use of **biological control** agents, and the use of modern vector surveillance methods to assess presence and size of **infestations**. However, it seems unlikely that effective vector abatement will be possible in the foreseeable future without the use of pesticides. At the same time, vector control remains a critical public health function in California. It is vital for maintenance of a high quality of life and for protection of the health of California residents. In addition to the annoyance and pain arthropods can cause by their blood-sucking habits, they also affect human health by causing allergic reactions, secondary infections, and most importantly, by their role as vectors of infectious disease organisms, such as the West Nile **virus** by mosquitoes.

Despite their role in the protection of California citizens from arthropods and other vectors, pesticide use is not without some risks. Pesticides, if used improperly, can have toxic consequences for people and pets, harm agricultural commodities, or disrupt aquatic and terrestrial wildlife. This is why applicators of public health pesticides must read, understand, and follow exactly the directions on pesticide labels before application.

Certification to apply public health pesticides in California is based on successful testing in several areas: A. Pesticide Application and Safety Training, plus one of the following: B. Mosquito Biology and Control, C. Arthropods of Public Health Significance, or D. Vertebrates of Public Health Significance. Individuals employed by public agencies must be certified by the California Department of Public Health to apply public health pesticides without supervision of a certified applicator.

This manual is designed to help prepare government agency employees for testing for competence under A. Safe and Effective Use of Pesticides. It is a revision of the manual titled: "Pesticide application and safety training for applicators of public health pesticides" by Michael W. Stimmann and Bruce F. Eldridge. **Bolded words** can be found in the glossary.

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Chapter 1

PUBLIC HEALTH PESTS AND DISEASE VECTORS

Public health pests are **organisms** which attack or annoy us in some way. When pests such as **insects** attack us by biting or stinging, disease **symptoms** may result. Some animal **species** harbor **pathogenic** microbial organisms such as **bacteria** or **viruses**. If an animal transmits such an organism to a person, and the person becomes ill, then the animal has served as a disease vector. Some organisms are included as public health pests not because they directly attack or annoy us, but because they help produce situations favoring the growth of pests or vectors. Weeds are an example of this public nuisance. **California Health and Safety Code** (2002 (j)) defines **public nuisances** as: "(1) Any property, excluding water, that has been artificially altered from its natural condition so that it now supports the development, attraction, or harborage of vectors. The presence of vectors in their developmental stages on a property is prima facie evidence that the property is a public nuisance. (2) Any water that is a breeding place for vectors. The presence of vectors in their developmental stages in the water is prima facie evidence that the water is a public nuisance. (3) Any activity that supports the development, attraction, or harborage of vectors, or that facilitates the introduction or spread of vectors."

A century ago it was easy to make distinctions between arthropods that were strictly pests and those which were vectors of disease organisms. Before 1920 only a few infectious diseases were known to be associated with arthropods. In fact, it had been only since 1876, when Dr. Patrick Manson demonstrated that mosquitoes were involved in the **life cycle** of filarial worms causing filariasis in humans that any insect appeared on a list of vectors. In the years since then, vector biologists and epidemiologists have increased this list many-fold, and further have shown that the **ecology** of many vector-pathogen relationships is very complex, and that vectors can have a number of roles in pathogen transmission and maintenance. Many arthropod species formerly considered only pests are now known to play vital roles in maintenance, amplification, and transmission of **vertebrate** pathogens. Thus, with the realization that certain arthropods can cause diseases other than infectious diseases in humans and other animals (see below) comes the conclusion that there are really few significant distinctions to be made between arthropod pests and arthropods of public health importance.

A core function in solving a problem caused by public health pests and disease vectors is proper identification of the suspected pest species. Often, this is a difficult task best left up to highly specialized biologists called **taxonomists**. Identifications made to the level of species can be of vital importance to understanding the habits, developmental sites, and **susceptibility** of the pests to control measures, but sometimes knowing basic biological characteristics of the major group to which the pest belongs can be extremely helpful. It is only after gaining experience working with groups of pests that pesticide **applicators** can know which pests can be identified by sight or with field guides, and which pests will need to be sent to specialists for identification.

Failure to properly identify a pest causing a problem may result in failure to solve the problem, and thus wasted time, money, chemicals, and effort. Proper identification will make it possible for you to understand much more about the pest, to make appropriate selection and application of management techniques in a way that solves the problem with minimal secondary effects to people and the environment.

Taxonomists divide living organisms into two large groups: the Animal Kingdom and the Plant Kingdom. A third Kingdom containing single-celled organisms such as bacteria and viruses are recognized by most taxonomists, but it is difficult to find agreement for the name of this Kingdom and just what should be included in it. One name that many taxonomists use for this Kingdom is the Protista. Most public health pests and disease vectors can be placed into two groups in the Animal Kingdom, the **invertebrates** (animals without backbones) and **vertebrates** (animals with backbones) and the loosely-defined category called **weeds** in the Plant Kingdom. This is the arrangement that will be followed in this manual.

HOW TO IDENTIFY PESTS

Although details will vary according to the type of pest to be identified, the basic principles of identification are the same for all pest species.

1. Compare collected specimens of the pest with identified specimens in museums or with photographs or other illustrations of identified pests.

2. Use an illustrated key. Keys are published guides to identification of biological organisms where the reader is led through a series of choices (usually two choices) on a certain characteristic of a specimen. If each choice is made correctly, the reader is eventually led to the correct identification of the specimen. Keys can be difficult to use for non-specialists because the characteristics contained in the choices are not always obvious. Keys that use choices such as “legs black” or “legs yellow” are easy to use. Those that ask “subcostal vein bifurcate” or “subcostal vein not bifurcate” are not.

3. Contact an authority, such as a farm advisor, agricultural commissioner, or biologist in the **USDA**, Cooperative Extension, public health department, or at a college or university.

INVERTEBRATES

Invertebrate animals include millions of animals that are not pests, such as sponges, starfish, earthworms, and squid. Nearly all the public health invertebrate pests are in the Phylum Arthropoda, and are called **arthropods**. The arthropods of public health importance are primarily the insects and their close arachnid relatives ticks, mites, and **spiders**.

INSECTS AND RELATED ARTHROPODS

INSECTS

There are well over one million species of insects, which means that there are more kinds of insects than any other kind of organism. Of these million-plus species, fewer than 100,000 are found in the United States. Of these, only a small number are important as public health pests.

In California we have about 100 common insect species of public health importance. Insects may cause diseases or annoyance to people in many ways, including:

- Causing allergic reactions
- Causing fright and annoyance
- Crawling, scraping, biting, bloodsucking, and other ways of attacking people
- Invading body tissues or organs of people
- Stinging people
- Transmitting disease organisms

- Serving as **host**s to disease organisms

Development of Insects

Insects have complex **life cycles**. Each insect changes form one or more times during its life. This change of form, called **metamorphosis**, may be divided into two types—simple and complete.

Insects with **simple metamorphosis** hatch from eggs and appear to be miniature copies of the **adult** insect: these are called **nymphs**. As the nymphs feed and grow, they shed their skin several times — a process called **molting**. When they complete their development, they are adults. Many common insects have simple metamorphosis, including cockroaches, termites, lice, thrips, true bugs, and aphids.

The more complex type of development among insects is called **complete metamorphosis**. This developmental pattern involves several complete changes in form during the growth of the insect. Insects with complete metamorphosis begin life as an egg. A **larva** hatches from this egg; the larva feeds, grows and molts several times. Then the larva enters a stage called a pupa. In this stage the insect assumes form unlike that of the larva or the adult. Pupae usually show little movement, but mosquitoes have an aquatic pupa that moves to the water surface to breath and sinks to bottom to hide. Mosquito pupae are called "tumblers".

In all insects with complete metamorphosis the adult insect develops within the pupa and eventually an adult insect emerges. It is the adult that mates, produces eggs, and starts the next generation. Common examples of insects with complete metamorphosis are beetles, moths and butterflies, flies, fleas, bees and ants.

Insects having complete metamorphosis present a special challenge to identification because larval stages usually look little like their adult forms.

Insect Form and Structure

Adult insects have a segmented external skeleton, three major body regions, six jointed legs, one pair of antennae, complex mouth parts, and (frequently) two pair of wings. The "skin" of an insect is in fact the segmented external skeleton, the **exoskeleton**, which covers the entire body. This exoskeleton protects the insect from enemies, gives the animal rigidity, and serves as the support of the soft internal body parts, including the muscles, nerves, blood system and various organs and glands. The exoskeleton is jointed to allow the animal to move, but it cannot grow. Therefore the exoskeleton must be shed from time to time to permit growth and development.

Adult insects have three major body regions: a head, a thorax, and an abdomen. The insect head bears the sensory organs — eyes, antennae, and mouthparts. The eyes of insects may be simple cells capable only of light detection, or they may be highly complex organs made of thousands of individual elements, capable of detecting movement, shapes and colors.

The thorax of the insect bears most of the organs of locomotion, including legs and wings. The legs may be highly modified for such activities as running, digging, or swimming. The wings, if present, may be simple and underdeveloped, or they may be highly developed for rapid and powerful flight.

The abdomen of the insect may have varying forms, but in the adult it lacks legs or wings. It may have some sensory organs on the hind end, but these are never true legs. The abdomen bears the reproductive organs of both the male and female insects.

Adult insects usually have two pair of wings, although certain groups, such as the true flies, have only one pair while fleas lack wings altogether. Insect wings may be almost featureless and transparent, like those of many flies, or they may be covered with brightly colored scales, like butterflies. In beetles, wings may be hardened into tough convex body coverings called elytra. The number of wings and their form and ornamentation are important factors in insect identification.

Insect mouth parts are as variable as the wings. The mouthparts may be modified for chewing plants, shaped into siphon-like tubes for sucking plant juices, developed into needle-like structures for piercing the skin of plants or animals, or modified into sponge-like structures for lapping up liquids.

Taxonomists place insects in the **Class Insecta**, and further divide them into about 30 **orders**. Mites, ticks, and spiders are arthropods related to the insects. Generally these insect relatives can be recognized by their overall appearance and by their eight-jointed legs. Their bodies are divided into two major regions rather than three, and they never have wings.

ARTHROPODS OF PUBLIC HEALTH IMPORTANCE: INSECTS

Fig. 1.1 Order Anoplura, a sucking louse

- No wings
- Piercing-sucking mouthparts
- Simple metamorphosis
- Suck blood of people and other vertebrates
- Pests: body lice, head lice, public lice

Fig. 1.2 Order Mallophaga, a chewing louse

- No wings
- Chewing mouthparts
- Broad head
- Feed on skin surfaces of birds and **mammals**
- Occasional human **infestations**

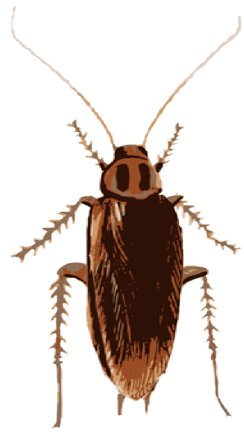

Fig. 1.3. Order Orthoptera, a cockroach

- Two pairs of wings or wingless
- Chewing mouthparts
- Simple metamorphosis
- Grasshoppers and crickets
- Pests: cockroaches

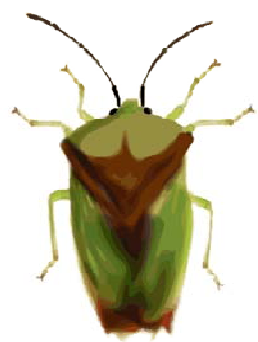

Fig. 1.4. Order Hemiptera, a true bug

- Two pairs of wings or wingless
- Top pair of wings partly leathery, partly transparent
- Piercing-sucking mouthparts
- Simple metamorphosis
- Pests: kissing bugs, bed bugs

Fig. 1.5 Order Lepidoptera, a butterfly

- Two pair of wings, usually scaled
- Sucking mouthparts
- Complete metamorphosis
- Damage many crops by feeding of caterpillars
- Rare instances of public health importance

Fig. 1.7. Order Diptera, a house fly

- One pair of wings
- Piercing-sucking or sponging mouthparts
- Complete metamorphosis
- Mosquitoes, flies, midges, and gnats are pests
- More species of public health importance than any other insect group.

Fig. 1.6. Order Celeoptera, a beetle

- Two pair of wings
- Outer pair hardened, inner pair soft
- Chewing mouthparts
- Complete metamorphosis
- Pests: blister beetles

Fig. 1.8. Order Hymenoptera, a wasp

- Two pairs of wings
- Most adults with narrow waists
- Complete metamorphosis
- Ants are common pests
- Bees and wasps sting people and other animals

OTHER ARTHROPODS

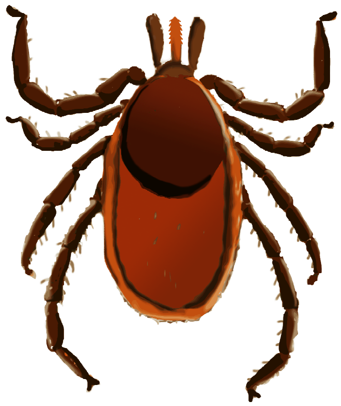

Fig. 1.9 Subclass Acari, a tick

- No distinct head
- Leathery or soft body
- No wings
- Parasitic on vertebrates
- Second only to mosquitoes in importance as vectors

Fig. 1.11 Subclass Araneae, a spider

- Fang-like mouthparts
- Most beneficial, a few poisonous
- Sucking mouth parts
- Parasitic on people and many other animals

Fig. 1.10 Sublass Acari, a mite

- Very small bodied
- Sucking mouthparts
- **Parasites** of plants and animals
- May transmit plant and animal pathogens

Fig. 1.12 Subclass Scorpiones, a scorpion

- Have stinging tail
- Some tropical species very dangerous
- Do not transmit pathogens
- Mainly pests in dry desert areas

VERTEBRATES

Vertebrates are animals with backbones. They include fish, frogs, toads, snakes, birds and **mammals**, including humans. Vertebrate pests are animals whose presence or activities are associated with human diseases or otherwise interfere with human interests and well-being. Introduced animals that alter the ecological balance in an area harming indigenous species may also be considered pest species. What may be a pest animal in some situations may be a highly desirable animal in others. For example, the beaver is considered a valuable fur-bearing animal; but because it can damage trees and create ponds that may serve as mosquito habitat it can also be a pest.

COMMON VERTEBRATES PESTS

FISH

Fig. 1.13 A pike

In California most fish pests are introduced species which compete with more desirable food and game fish. There are several invasive, non-native fish species in California that are considered pest species. The northern pike is such as species, and hundreds of millions of dollars are spent in California on efforts to remove it from lakes and reservoirs. Other fish species are undesirable because they serve as intermediate **host**s for parasites of people and other vertebrates. In most areas of the state, mosquitofish are a valuable and important biological tool for vector control agencies, however there are locations where mosquito fish should not be used and may be considered pest. It is essential to know and follow state and federal law when introducing any non-native species.

AMPHIBIANS AND REPTILES

Fig. 1.14.A rattlesnake

Occasionally, toads or frogs may become nuisances around homes or parks. A few reptiles, in certain situations, might be considered pests. Most snakes are not **poisonous**, and they are generally beneficial. However, rattlesnakes are common in some areas of California, and when people come in contact with them there is a risk of receiving a poisonous bite. There are 6 species of rattlesnakes in California. The western diamond back rattlesnake is the most dangerous, and is responsible for most human deaths from snake bite in North America. Even so, fatal snake bites are rare, with only 10-15 occurring each year in all of North America. This is far fewer than deaths caused by stings of bees and wasps.

BIRDS

Many species of birds occur in California, many of which are beneficial and protected by law. However, birds can be serious pests and many species are involved in movement and amplification of human disease organisms. Most mosquito-borne viral diseases are principally diseases of birds, with humans being only secondarily infected.

Fig. 1.15 A crow

Some species of birds can become pests in urban areas when they roost on buildings, leaving accumulations of droppings and otherwise causing damage. There also may be a risk of disease to humans who come in contact with droppings. In rural areas, birds may damage crops either by feeding directly on plant parts such as fruit, or by disrupting fields while feeding on seeds.

Control of bird pests requires specialized knowledge and techniques, and must be done in accordance with state and federal laws. Some vector control technicians are certified for vertebrate vector control and may work directly with birds. Most vector control technicians are not adequately versed in birds or the state and local laws to work directly with them. Anyone planning to undertake a project directed at birds should first consult his or her County Agricultural Commissioner and the California Department of Fish and Game.

MAMMALS

All mammals have warm blood, hair, and feed their young milk. Some mammal pests can represent serious potential risks to the health of humans and domestic animals. By biting, carnivorous mammals such as dogs, skunks, or coyotes may be vectors to humans of the virus causing rabies. Mammals may also serve as the primary hosts of several diseases that are transmitted (i.e., vectored) by arthropods. Plague (transmitted by fleas) and tularemia

Fig. 1.16 A coyote

(deer flies and **ticks**) are examples of such diseases, although humans can become infected directly by the bacteria causing the diseases in other ways as well. Hantavirus infection in people occurs by yet another route, where individuals typically become infected with the virus through contact with urine and feces of **rodents.**

Mammals can also be pests by killing livestock or damaging crops, lawns, stored goods, or structures.

WEEDS

A **weed** is any plant growing where it is not wanted. Because of this, weeds cannot be placed in any meaningful taxonomic classification. However, there are many non-native species that are legally considered weeds, despite their desirable qualities in flower gardens. The butterfly bush and Scotch Broom are prized by many gardeners in California because of its vigor and beautiful floral display, but others discourage the planting of this foreign species because of its tendency to grow out of control and crowd out native species.

Weeds can be damaging because they may:

- Compete with planted crops for water and nutrients, resulting in reduced crop yields, and impaired crop quality.

- Increase agricultural production costs.
- Interfere with proper operation of drainage and irrigation structures.
- Compete with indigenous plant species resulting in ecological damage and a corresponding loss of biological diversity.
- Degrade wildlife forage or hiding cover, or create habitat for species not previously in an area.
- Promote production of arthropod pests, especially mosquitoes, by providing protection from predacious fish and insects.
- Affect public health by producing allergens or causing contact dermatitis.

COMMON FORMS OF WEEDS

While there are about 500 plant species in California that generally are considered weeds, Most of these can be placed into one of two groups:

1. Narrow-leaved plants, including grasses, sedges, rushes, cattails, and a few others. The narrow-leaved weeds generally have parallel veins in the leaves.

2. Broad-leaved plants such as willow, oak, mustard, dock, pigweed, purslane, and bindweed. These weeds may be recognized by the presence of a net-like pattern of veins in the leaves. This is a useful classification for **weed control** purposes because these broad categories reflect not only a taxonomic separation (monocots and dicots) but are often important for the selection of an appropriate **herbicide** or other control strategy.

Weeds may be **terrestrial** or **aquatic**. Many **aquatic weeds** are important in mosquito abatement because they contribute to mosquito problems.

LIFE CYCLES OF WEEDS

Plants also can be classified according to their life cycles as **annuals**, **biennials**, or **perennials**. Grouping weeds in this way can be helpful in designing weed control management plans.

Annuals mature in one season and are propagated by seeds. **Summer annuals** grow from seeds that sprout in the spring, mature, and reproduce before dying in the winter. Among the common summer annuals are barnyard grass, puncture vine, Russian thistle, and pigweed. **Winter annuals** germinate in the fall or winter and grow until spring when they flower, produce seed, and die. Among the common winter annuals are chick-weed, mustard, wild oats, and annual bluegrass.

Biennials require two years to develop and complete their life cycles. These plants grow vegetatively (without flowering) through the first year and flower and produce seed during the second year. The plant then dies and will not re-appear at the site unless the seeds germinate and new plants grow. Common biennials are purple starthistle, musk thistle, mullein, and bristly ox tongue.

Perennials are plants that live three years or longer. These plants flower and set seed without dying. Perennials live indefinitely. They may die back to the ground in the winter, but re-grow in the spring. Common examples of perennials are Johnsongrass, field bindweed, dandelion, plantain, willow, and poison oak.

Perennials are found throughout the Plant Kingdom, and they may take many forms. Some are herbaceous soft bodied plants, others are shrubs, and some are trees. Many perennials can store food underground in **rhizomes,** bulbs, or tubers, which makes these plants difficult to kill by mechanical or chemical means.

WEEDS AND VECTOR CONTROL

Weed control in connection with vector control programs is limited to control of plants which may play a direct role in production of vector species and plants that prevent access to areas of vector production. Examples include overgrowth of cattails, tules, and bull rush. These plants can create areas of stagnant water and thick vegetation thus creating prime mosquito breeding habitat and making vector control difficult.

Chapter 2

PESTICIDE CLASSIFICATIONS AND FORMULATIONS

Pesticides are defined as substances or mixtures of substances intended for controlling, preventing, destroying, repelling, or attracting any biological **organism** deemed to be a pest. **Insecticide**s, **herbicide**s, **defoliants**, **desiccants**, **fungicide**s, **nematicides**, **avicides**, and rodenticides are some of the many kinds of pesticides.

CLASSIFICATION OF PESTICIDES

Pesticides may be classified in a number of ways; these classifications can provide useful information about the pesticide chemistry, how they work, what they target, etc. Following are brief descriptions of some commonly used classification systems.

BY CHEMICAL NATURE

One traditional classification of pesticides places them in one of two groups: **organic** and **inorganic**. **Organic pesticides** are based on chemicals having carbon as the basis of their molecular structure. The chemicals in organic pesticides are more complex than those of **inorganic pesticides**, and usually do not dissolve easily in water. Inorganic pesticides are simpler compounds. They have a crystalline, salt-like appearance, are environmentally stable, and usually dissolve readily in water. The earliest chemical pesticides were inorganic, and included substance such as sulfur and lime.

The vast majority of modern pesticides contain an organic chemical. There have been hundreds of pesticides developed based on organic chemicals, often with oxygen, phosphorus, or sulfur in their molecules, in addition to their basic carbon structure.

Organic pesticides can be subdivided into two additional groups: the **natural organics**, and the **synthetic organics**. The natural organic pesticides (sometimes just called "organics") are derived from naturally occurring sources such as plants. Rotenone and pyrethrum are examples of natural organic pesticides.

Synthetic organic pesticides (usually just called "synthetics") are produced artificially by chemical synthesis. This group comprises most "modern" pesticides (i.e., discovered or used as insecticides post-World War II), and includes DDT, permethrin, malathion, 2, 4-D, glyphosphate, and many, many others.

BY TARGET PEST SPECIES AND PESTICIDE FUNCTION

Pesticides are sometimes classified by the type of pest against which they are directed or the way the pesticide functions. Table 2.1 is an example of this sort of classification.

INSECTICIDES AND ACARACIDES: CLASSIFICATION BY CHEMISTRY

Insecticides are designed to control **insects**, and acaracides control ticks and **mites**. In public health applications they are most commonly used to control mosquitoes, flies, ticks, mites, lice, and fleas. Since insecticides and acaracides are often the same pesticides, they are not discussed separately here.

Organochlorines (=chlorinated **hydrocarbons**) represent the one of the first group of pesticides synthesized, and include the well-known insecticide DDT. Although DDT is still legally used for vector control in some areas of the world (particularly where malaria occurs), DDT's registration for nearly all uses was suspended by the **EPA** many years ago, and consequently, it is no longer used in the United States. Most other organochlorines used for arthropod control, including chlordane, dieldrin, and lindane, have met similar fates.

Table 2.1 Classification of insecticides.

Pesticide	Target Pest / Function
Acaricide	Mites, ticks
Algaecide	Algae
Anticoagulant	Rodents
Attractant	Attracts insects or birds
Avicide	Birds
Bactericide	**Bacteria**
Defoliant	Plant leaves
Desiccant	Disrupts water balance in arthropods
Fungicide	Fungi
Growth regulator	Regulates insect and plant growth
Herbicide	Weeds
Insecticide	Insects
Miticide	Mites
Molluscicide	Snails, slugs
Nematicide	Nematodes
Piscicide	Fish
Predacide	Vertebrate **predators**
Repellent	Repels vertebrates or arthropods
Rodenticide	Rodents
Silvicide	Woody vegetation

Organophosphates Although a few organophosphate (OP) **formulation**s remain available for vector control, their use has dramatically decreased because of resistance to OPs, the potential for **non-target** effects, and the development of alternative **products.** Members of this group contain phosphorous in their molecules. Products currently **labeled** for vector control include naled, malathion, and some formulations of dursban. Organophosphates are considered by most to pose a greater human health risk for pesticide **applicators** than other families of pesticides.

Carbamates are chemically similar in structure to organophosphates, but whereas OPs are derivatives of phosphoric acid, carbamates are derivatives of carbamic acid. Pesticides in this group used for vector control in California include carbaryl (Sevin®) for dusting rodent burrows to control fleas, propoxur (Baygon®) for use against insect pests, and certain brands of bee and wasp control sprays. Carbamates also pose a relatively high risk for human **poisoning**. Some carbamates are herbicides.

Pyrethrum is a natural organic insecticide that is derived from plants in the genus *Chrysanthemum.* There are about 30 **species** in the genus, most of which use the generic name as their common name. The insecticide is produced by grinding of the flowers, thus releasing the active components of the insecticide, called **pyrethrins**. The main active constituents are pyrethrin I and pyrethrin II plus smaller amounts of the related cinerins and jasmolins.

Insecticides containing pyrethrins are neurotoxic to nearly all insects. They are harmful to fish, but are far less **toxic** to **mammals** and birds than many synthetic insecticides and are **non-persistent**, breaking down easily on **exposure** to light. They are considered to be amongst the safest insecticides for use around food.

Pyrethrin-containing insecticides are used widely in California for vector control. They are broadly labeled, and can be used in both rural and urban areas in a variety of habitats. Pyrethrins are usually mixed with PBO (piperonyl butoxide), which acts as a **synergist**. Synergists are materials that are not necessarily pesticidal by themselves, but have the effect of increasing the toxicity of insecticides with which they are mixed. Without PBO, insects treated with the same **dose** of pyrethrins would be knocked down, but would eventually recover.

Fig. 2.1 *Chrysanthemum coronarium* in the Tel Aviv garden (from Wikipedia).

Recent studies suggest that PBO may have a longer residual life in aquatic systems than previously thought, possibly acting to increase the toxicity of other chemicals to benthic organisms (i.e., animals inhabiting the sediment layer of aquatic environments). Additional studies should clarify the significance of vector control applications to these populations.

Pyrethrins are highly toxic to fish and their direct application to water is restricted.

Pyrethroids are synthetically produced molecules that are chemically similar to pyrethrins. Pyrethroids are not persistent. At **rates** applied for vector control, they break down quickly in sunlight, and are rarely present after just a few days. The **mode of action** of pyrethroids is the same as that of pyrethrins. Most pyrethroids are also synergized with PBO. Several generations of pyrethroids have been produced, with the latest formulations being effective at extremely small doses. Some of these new compounds may not break down as readily in sunlight as do pyrethrins, and in some cases pyrethroid synergists may not markedly improve their effectiveness.

Pyrethrins and pyrethroids are now among the most common public health pesticides used in California, especially for the control of **adult** mosquitoes. Their use now far outstrips that of conventional synthetic pesticides such as organochlorines and organophosphates.

Biorationals (biorational pesticides or biopesticides) are a group of pesticides that are considered relatively non-toxic to humans and are also environmentally safe. The EPA defines biorationals as "certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals." Most pesticide specialists interpret the word "derived" broadly, and include synthetic pesticides that resemble natural substances. Ware and Whitacre, in *The Pesticide Book*, refer to biorationals as 21st century pesticides, and point out that the term has no single or legally clear definition. Biorationals can be separated into two groups: (1) **biochemical** (**hormones**, enzymes, **pheromones**, and natural insect and plant regulators) and (2) microbial **(viruses**, bacteria, **fungi**, protozoa, and **nematodes**). Among public health pesticides, methoprene (Altosid®) would fall into the first group, *Bacillus thuringiensis israelensis* (Bti) into the second. Because there is presently no strict legal definition for the term biorational, many will realize that some products, such as Bti, will satisfy the definitions for both biorational and **biological control** agent.

The action of biochemical biorationals is based on the interruption of natural growth processes of arthropods. They are not particularly selective among arthropod species, but generally have extremely low toxicity for vertebrates, including people. Insect growth regulators (**IGRs**), chitin **inhibitors**, plant **growth regulator**s, and chromosterilants are included in this group. For vector control, the use of methoprene (an insect growth regulator) in mosquito control far outweighs all other uses. For many years after their introduction, IGRs were considered immune to the development of resistance by **target pests**. However, resistance has now been detected against some IGRs in specific locations in California and elsewhere. Diflubenzuron (Dimilin®) is a good example of an IGR that mosquitoes have shown resistance to.

Microbial pesticides kill arthropods either by **toxins** released by microbial organisms, or by infection by the organisms. Two common pesticides that fit within this group include the bacterial toxin produced by Bti, and the live bacteria, *Bacillus sphaericus* (Bs). Products containing both of these bacteria are used against mosquito **larvae**, with Bti being effective in killing black fly larvae as well. Most microbial pesticides are more selective than biochemical pesticides.

MATERIALS APPLIED TO WATER SURFACES

Petroleum oils are refined from crude oil and in vector control are used both as **carriers** for insecticides, and more directly (as **active ingredients**) when mixed with a **surfactant** and applied to the water surface (i.e., Golden Bear 1111®) as a suffocating agent against mosquito larvae and **pupae**. Measured by weight, petroleum oils are by far the most common **active ingredient** (>90%) used for vector control in California

Alcohols are also used as surface control chemicals against mosquito larvae (i.e., Agnique®). These materials act by reducing surface tension of the water, eventually leading to the drowning of mosquito larvae or pupae.

Water surface control insecticides have several advantages over conventional insecticides. Oils and alcohols will kill mosquito pupae as well as larvae, and because there action is more physical than biochemical, they do not lead to development of pesticide resistance. The disadvantage of these products is they kill non-target organisms that either breath at the water surface (e.g., small aquatic beetles), or that depend on surface tension of the water (e.g., water striders).

OTHER CLASSIFICATIONS OF PESTICIDES

Pesticides can also be classified by how they enter the target organism or where they act.

Stomach toxicants enter an insect's body through the mouth and digestive tract, where they are absorbed into the insect's body. **Stomach poison**s are acquired during feeding. In vector control, this category includes bacteria, or their toxins, applied to the water where filter-feeding mosquito or black fly larvae will consume the poison. These microbial insecticides kill by destroying the midgut (or stomach) of the larvae. Ants, cockroaches, and other pest insects with chewing mouthparts can be controlled by incorporation of insecticides into **baits** of various types. The site of insecticidal action varies. Rodents are also often controlled for using **ingested anticoagulants**. They die from internal bleeding, the result of loss of the blood s clotting ability and damage to the capillaries. Because anticoagulant baits are slow in action (several days following the ingestion of a **lethal** dose), the target animal is unable to associate its illness with the bait eaten. As a result, **bait shyness** usually does not occur. This **delayed action** also has a safety advantage because it provides time to administer the **antidote** (vitamin K1) to save pets, livestock, and people who may have accidentally ingested the bait.

Contact toxicants generally enter the pest or plant's body either by exposure to water treated with the chemical or direct contact with an **aerosol** (e.g., adult mosquitoes flying into an insecticidal "fog"), or by exposure to some treated surface, such as leaves. Like most insecticides, these poisons act upon the nerve and respiratory centers of arthropods. Most adult mosquito control products are contact toxicants.

Fumigants are volatile compounds that enter the bodies of insects in a gaseous phase. There are no longer any fumigants registered for use for control of public health insect pests in California. (But are sometimes used in rodent control)

Systemic toxicants are absorbed by plants, pets, or livestock and are disseminated throughout the organism via the vascular system. When a pest organism feeds on the plant or animal, they ingest the toxicant. Some toxicants are quickly lethal to the pest; others work to prevent the pest from maturing. Application in vector control is typically used for tick and flea control on pets, as well as dog heartworm prevention.

Chemical repellents used in public health applications prevent bloodsucking insects such as mosquitoes, black flies, and ticks from biting humans, livestock, or pets. The most widely used chemical used in repellent formulations to protect people is dimethyl toluamide, or DEET. In recent years a variety of formulations have been developed to minimize DEET's unpleasant characteristics when used as a skin repellent, and also to lengthen the duration of its effectiveness. Since the end of the 20th century, several repellents with an entirely new chemical basis have been released, some rivaling the effectiveness of DEET. (Mechanical repellents, such as high frequency emitters, marketed for insects or other pests are generally unproven and ineffective)

FORMULATIONS WITH COMBINATIONS OF PESTICIDES

When two or more chemicals can be mixed safely, or used in combination, they are said to be **compatible.** These combinations can be a pesticide mixed with another non-pesticide chemical, or can be two or more pesticides that are combined in the same tank mix. The reasons for combining pesticides are:

1. To increase the effectiveness of one of the chemicals. As mentioned above, this is called synergism. The material added to increase the effectiveness of the primary chemical is called a **synergist**. The synergist may not necessarily be pesticidal by itself, but increases the effectiveness of the pesticide with which it is combined. The best-known example of the use of a synergist is the addition of piperonyl butoxide (PBO) to pyrethrum, pyrethrins, or some synthetic pyrethroids. Without the addition of PBO, flying insects may be knocked down by these insecticides, but will later recover and fly away.

2. To provide better control than that obtained from one pesticide. Applicators sometimes combine 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 combined chemicals on different segments of the pest population. One should always check the label prior to verify the safety and legality of mixing pesticides.

3. To control different types of pests with a single application. Frequently, several types of pests need to be controlled at the same time. It is usually more economical to combine the pesticides needed and make a single application.

When two or more pesticides cannot be used in combination, they are said to be **incompatible.** Some pesticides are incompatible because they will not mix, others because even though they mix, they do not produce the desired results. Some combinations of chemicals result in mixtures that produce an effect which is the opposite of synergism. This effect is called **antagonism** and may result in chemical reactions which cause the formation of new compounds. In other cases incompatibility may result in separation of the 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 the screen and **nozzles** of application equipment.
- Various types of **phytotoxicity** may occur.
- Excessive **residues** may result.
- Excessive **runoff** may occur.

Another less familiar, but extremely important, undesirable effect of combining certain pesticides is **.** Some of the organophosphorous pesticides potentiate (or activate) each other as far as animal toxicity is concerned. In some cases, the combination increases the toxicity of a compound that is normally of very low toxicity, so that the result is a compound that is highly toxic to people, other animals or plants.

Some pesticide labels indicate known **compatibility** problems. Some pesticide **formulation**s are prepared for mixing with other materials and are registered for pre-mixes or for tank mixes. If this is true, it will be so indicated on the label.

Prior to tank mixing a combination of chemicals, refer to the compatibility charts that are available through your pesticide dealer or from various other sources. You should also remember that organophosphates, and some herbicides are more **persistent** in the environment and multiple applications several days apart may result in excessive residue, phytotoxicity, or livestock poisoning.

HERBICIDES

Vector control agencies frequently use herbicides to kill plants, or inhibit their growth when the plants either contribute to vector ion, or prevent technicians from being able to control vectors efficiently. Herbicides have been used in association with vector control operations for many years. In the early 1900s organic materials such as iron sulfate, copper nitrate, and sulfuric acid were used. In the 1940s, 2,4-D, a synthetic organic chemical, was developed as a selective herbicide. Since that time, hundreds of herbicides have been synthesized.

Vector control technicians should take special care in mixing and applying herbicides, and in learning the proper safety precautions needed for their use. Herbicide mixing, storage, and application can pose significant occupational health risks. Also, herbicides often present greater long term environmental risks than other pesticides, particularly to groundwater. Herbicides can create significant economic damage to croplands in agricultural areas.

Herbicides can be separated into **organic** or **inorganic** materials. Organic herbicides have a carbon based molecular structure and usually act by altering the normal growth pattern of the plant. Organic herbicides may be further divided into two major groups—the petroleum oils and the synthetic organic herbicides. The petroleum oils, refined from crude oil, can be used as either herbicides or insecticides. When formulated as herbicides, they usually are applied without dilution. Synthetic organic herbicides are artificially created in laboratories, and are made up of carbon, hydrogen, often nitrogen, and other elements. Included among the common synthetic organic herbicides are 2,4-D, and glyphosate.

Inorganic herbicides are often in the form of a salt, or contain a metal that is toxic to plants, often preventing proper uptake of water or inhibiting movement of material across cell walls. Inorganic herbicides are chemical compounds which do not have a carbon structure. The inorganics include such common materials as salt, copper sulfate, sulfuric acid, and sodium chlorate. These herbicides are extremely persistent and have caused serious soil pollution problems in some areas. Many are restricted materials.

Herbicides are applied for control of plants in a variety of ways, and the way that they are used affects the target plants differently. Although herbicides are formulated and used in ways similar to insecticides, because they are applied to control plant growth, their modes of action tend to be very different.

CHEMICAL GROUPS OF HERBICIDES

Devising a simple classification scheme for herbicides based on their chemical group is difficult. To classify herbicides by chemical group requires at least 20 different categories, only a few of which will be mentioned here.

Phenoxies

Phenoxy herbicides are used in both crop and non-crop areas for control of most **annual** and **perennial broadleaf** weeds. Some commonly used phenoxies include 2,4-D, MCPA, dichlorprop (2,4-DP), and 2,4-DB (Butoxone® or Butyrac®).

These herbicides are primarily plant growth regulators and affect the actively growing tissue of the plant. The ester **formulations** of the phenoxies are relatively volatile and turn into a gas during hot summer days. Care should be taken not to use them around **susceptible** broadleaf crops and **ornamentals**.

Triazines

Triazines are used to control annual grasses and broadleaf weeds. Some commonly used triazines include atrazine (AAtrex®), simazine (Princep®), and metribuzin (Sencor® or Lexone®). The triazines are primarily used as non-selective **pre-emergent** herbicides. Prometon (Pramitol®) can be used as a pre-emergent or post-emergent herbicide on non-crop land. Triazines affect plants by inhibiting their ability to photosynthesize. Triazines have been found as contaminants in groundwater in the USA.

Thiocarbamates

Thiocarbamates are used for control of annual grass seedlings and broadleaf weed seedlings. EPTC (Eptam®) is a commonly used thiocarbamate. They inhibit the meristematic growth of plants, such as root and shoot tips and are applied as a **pre-plant**, soil incorporated treatment.

Ureas and Uracils

Ureas and uracils have several similar uses and their modes of action have many features in common. Diuron (Karmex®) and tebuthiuron (Spike®) are commonly used ureas, and bromacil (Hyva®) is a widely used uracil. These compounds are primarily applied to soil as **pre-emergence** herbicides, but they also provide **post-emergence** control for certain plants. The ureas and uracils affect plants by inhibiting their ability to photosynthesize.

Benzoics

Benzoic acid herbicides are used in both crop and noncrop areas for control of numerous broadleaf weeds and annual grasses. Banvel is a commonly used member of this group. The benzoics are effective when applied either to the plant **foliage** or to the soil and work as plant growth regulators that affect the actively growing tissues of plants.

Acetanilides

The acetanilide herbicides are used for control of many annual grasses and broadleaf weeds. Common acetanilides include alachlor (Lasso®), acetochlor (Harness® or Surpass®), metolachlor (Dual®), and pronamide (Kerb®). This group can be applied either pre-emergence or pre-planting in crop areas.

Sulfonylureas

One of the most recently developed groups of herbicides, the sulfonylureas are highly active compounds used at extremely low rates. They are used to control many **broadleaf plants** in small grain crops, pastures, and noncrop areas. Commonly used sulfonylureas include chlorsulfuron (Glean® and Telar®), triasulfuron (Amber®), sulfometuron (Oust®), and metsulfuron (Ally® and Escor®t).

These compounds are usually applied as foliar treatments; however, they also control newly emerging broadleaf seedlings. Chlorsulfuron and sulfometuron are sulfonylureas that are more persistent in nature and will carry over into a second year when applied in high-pH soils. Extremely low residues from wind **drift** or in wind blown soil can cause significant losses in certain crops including corn, potatoes, and sugar beets.

Imidazolinones

A new and important herbicide family is the imidazolinones. It includes imazethapyr (Pursuit®), imazamethabenz (Assert®), and imazapyr (Arsenal®). This group act as biosynthesis inhibitors within the actively growing plant. These are **broad spectrum** herbicides and may be used against grass, broadleaf annuals, biennials, and perennials, vines, brush, and trees. Care must be taken around trees as root uptake from soil may result in death.

HERBICIDES BY USE

Herbicides can also be classified by their pattern of use. Examples are selectivity (selective versus non-selective); whether they are applied to soil or plant foliage; and by how the herbicide moves within the plant (systemic versus non-systemic). The important classification for vector control use is where an herbicide may be used (terrestrial, aquatic, ditch bank, etc.).

Classification can be further complicated by the differences in effects of herbicides at different dosages. For example, some may act to help regulate plant growth and production of the seed when applied at a low rate, while at higher rates, they will kill plants. Other herbicides are selective for broadleaf plants at low application rates, but are non-selective when applied at higher rates.

Selective herbicides

Selective herbicides can be used to control certain plant species without injuring others. This characteristic can be used to control weeds while avoiding harm to desirable plants. Other selective herbicides may affect foliage of plants while leaving plant roots unaffected. Still other examples of selective products are herbicides that can be applied to soil or water before (pre-emergence) or after (post-emergence) the active growing season of plants. Some of these products can control growth of all plants, others affect only certain species. Perhaps the most common selective herbicides are those that affect broad-leaf plants, but not grasses. This selectivity is based almost entirely on the shape and size of the target foliage. In these cases, some herbicide **formulation**s will wet broad-leaved plants but run off on grasses.

The application of selective herbicides may kill only the parts of the plant actually sprayed. In this case they are considered contact herbicides. Complete weed kill using contact herbicides requires well-directed and properly applied sprays. Complete coverage of the weed is a must.

Some herbicides are applied to the leaves of plants and absorbed into their stems and roots (translocated) causing the death of the entire plant. Because species of plants vary in their **susceptibility** to these systemic herbicides, these herbicides are selective to some degree.

Examples of selective herbicides are 2,4-D, dicamba, and picloram. Pre-emergent herbicides with selective **properties** are atrazine, trifluralin, and oryzalin.

Non-selective herbicides

Some herbicides are non-selective and must be used with extreme **caution**. They are used primarily in situations where complete removal of vegetation is desired, such as on transportation rights-of-ways. Some commonly used nonselective herbicides include glyphosate, imazapyr, bromacil and paraquat.

Non-selective herbicides can be applied to foliage as contact herbicides or as translocated herbicides. They may also be applied to soils where they kill nearly all plants growing there. Some soil-applied herbicides are available as fumigants.

Even selective herbicides can damage desirable plants if not used in strict compliance with their labels. In this regard, accurate dilution and **calibration** of equipment is critical. Since the distinction between weeds and non-weeds is so subjective, designing sound **weed control** strategies requires considerable knowledge and planning.

Extra care must be taken in applying **non-selective pesticides**. Do not apply them in sloping areas or where soil may be taken for use in a different location.

Contact Herbicides

Contact herbicides are applied directly to the plant, and may affect only the part of the plant contacted. This type herbicide can be used for preventing growth of brush and tree limbs into pathways. Bromoxynil, paraquat, and diquat are examples of contact herbicides.

Systemic Herbicides

Herbicides that move from one part of the plant to another such as from the leaf to the roots are called systemic. These **formulations** are particularly useful for control of deep rooted perennial vegetation.

Systemic herbicides may enter the plant through the roots or the leaves then move via the plant's vascular system to affect the entire plant. Commonly used systemic herbicides applied to plant foliage include MSMA, glyphosate, dichloprop, 2,4-D, dicamba, picloram, and chlorsulfuron.

Simazine, diuron, pronamide, and EPTC are examples of soil applied systemic herbicides. Some herbicides including triazines and thiocarbamates will translocate through both processes; however, they primarily work through root uptake which is the recommended method of application.

Plant Growth Regulators

Plant growth regulators (PGRs) are herbicides used for regulating or suppressing the growth of a plant and/or seeds. PGRs may be very selective, preventing growth or seed production of certain grasses, brush, or annual broadleaf plants without affecting non-target grasses. PGRs usually are applied directly to the foliage of the target plant.

Mefluidide (Embark®), sulfometuron (Oust®), and fosamine ammonium (Kernite®) are examples of selective PGR's.

FACTORS AFFECTING FOLIAR APPLIED HERBICIDES

There are many factors that affect the results of foliar herbicide applications. Some of these are:

- The age of the plants treated.

- The season of the year of applications.
- The **life cycle** stage of the plants (budding, flowering, overwintering, etc.).
- The type of life cycle of the plant (annual, biannual, or perennial).
- The degree of maturity of the plant.
- The time of day of the application.
- Weather conditions at the time of application.
- The life form of the plant treated (woody, succulent, broad-leaved, grassy, etc.).
- The morphology of the plant treated (cuticle thickness, presence of leaf hairs, etc.).

FACTORS AFFECTING SOIL APPLIED HERBICIDES

SOIL CHARACTERISTICS

The physical and chemical characteristics of the soil as well as the climatic conditions will determine the effectiveness of a soil applied herbicide, the persistence of the herbicide in the soil, and the potential movement of the herbicide through the soil (leachability).

Both soils and herbicides vary in their polarity of their constituent particles. Both can be negatively or positively charged or have a neutral charge. This will affect the movement of herbicides thorough soil and also the persistence of the herbicides applied.

Soil texture also will influence movement and persistence of herbicides. Light soil types (sands and sandy loams) tend to have large pore openings between the particles that allow water to move down through the soil profile rapidly. This will promote the more rapid movement of herbicides through these soils, but more rapid **leaching**, and thus lower persistence.

Herbicides applied to heavy soils (clay loams and clays) behave in the opposite manner. They move slowly through these soils and tend to remain longer. Medium texture soils (loams and silt loams) respond in an intermediate fashion to herbicides applied.

Before application of an herbicide to a soil a pesticide technician should know the characteristics of the soil to be treated. This can be determined by a soil test. A local county extension office or a Natural Resources Conservation Service (NRCS) Office can furnish information on collection of soil samples for testing. Herbicide labels have recommended rates of application based on the soil texture. The texture of soil basically is determined by the percentage of sand, silt, clay, and organic material in it. Generally, heavier soils require higher amounts of herbicide for plant control than lighter soils.

Other factors that can affect herbicide applications to soils include that amount of organic matter in the soil, the degree of compaction of the soil, the moisture content of the soil, and whether an underlying hard-pan is present below the soil surface.

HERBICIDE PERSISTENCE

Other factors beyond those already discussed that affect herbicide persistence include the rate of application, soil temperature, exposure to sunlight, microbial and chemical decomposition, solubility of an herbicide, and precipitation. These factors also affect how fast an herbicide will be degraded, and how deep it will leach through the soil.

FACTORS TO CONSIDER IN PLANNING HERBICIDE APPLICATIONS

When choosing an herbicide to use for weed control, consider the vegetation that is close to the application site. Take precautions to avoid movement of herbicides into surrounding areas, especially if valuable vegetation is nearby.

Herbicide applications should be avoided when it is raining, or in areas where overland water flow is likely to occur. Applications should likewise be avoided in heavy winds. The **danger** of drift in high wind conditions is especially high in open areas with little protection from wind.

Volatile herbicides such as the 2,4-D ester **formulation** and dicamba will **vaporize** during hot summer days, and danger of herbicide drift will be greater under these circumstances. Danger from volatilization will be included on the pesticide label.

General recommendations on herbicide labels include:

- Mix and apply herbicide formulations having a low **volatility**.
- Apply herbicides using the lowest practical spray pressures.
- Apply herbicides using the largest practical spray droplet size.
- Apply herbicides when wind speed is low.
- Do not apply herbicides during a temperature inversion (when air is coolest at ground level, gets warmer up to a certain height, and gets cooler from that point up).

MANAGEMENT OF AQUATIC PLANT SYSTEMS

Management of vegetation in and around lakes and ponds, other than limited application of algaecides and control of emergent vegetation, is beyond the scope of activities covered by a vector control technician license.

Active management of rooted lake or pond vegetation and/or fisheries is very complicated and takes specialized knowledge of organic and inorganic chemistry, micro-biology, fisheries biology, and a variety of environmental disciplines.

Vector control programs and technicians may not engage in lake and pond management, including control of aquatic vegetation, without additional training and certification.

In summary, herbicide activities by public health pesticide applicators should only target vegetation that directly contributes to vector production or prevents technicians from efficiently controlling vectors.

RODENTICIDES

Nearly half of all species of mammals are **rodents,** but only a few are of public health importance. Domestic rats and mice are the primary targets of pesticide applicators in urban and suburban situations, but rodents also are associated with rural diseases such as plague and hantavirus diseases. Control of these kinds of diseases by use of **rodenticides** is impractical except in unusual circumstances. Other rodents that may present problems for public health agencies are squirrels, gophers, hares, and rabbits. These problems may involve the roles of the vertebrates as disease reservoirs, or may involve activities of rodents such as ground squirrels or gophers in damaging water impoundment dikes used for mosquito control.

Rodenticides may be typically classified as first or second generation. There are a few instances where the product may not fall under either heading. A first generation rodenticide requires higher concentrations (usually between 0.005 and 0.1%) and consecutive intake over multiple days so a lethal dose may bio-accumulate. There are considered less toxic than second generation agents. Second generation Rodenticides are applied in lower concentrations in baits (usually in order 0.001-0.005%) and are lethal after a single ingestion of bait. Second generation rodenticides are also effective against rodents that are **resistant** to first generation anticoagulants. The second generation anticoagulants are sometimes referred to as "superwarfarins".

The most widely used group of rodenticides is the coumarins. The best-known member of this group is Warfarin, which derives its name from the Wisconsin Alumni Research Foundation, where it was originally developed. Coumarins affect all mammals, including humans, by serving as blood anticoagulants. Coumarins kill rodents over time by two related effects. They inhibit prothrombin formation, thus disrupting clotting, and they also damage capillaries, resulting in internal bleeding.

Warfarin was very successful as a rodenticide when it was first introduced because rodents did not exhibit bait shyness because of the extended period of action of the coumarins. However, physiological resistance to coumarins has been reported in rats in some areas. Some newer coumarins have been developed (e.g., brodifacoum, bromadiolone) that will kill rodents in 4–7 days after a single feeding. These materials can be used where rodents are encountered that are resistant to conventional anticoagulants.

Indandiones is another group of rodenticides. Although indandiones belong to a different chemical class than the coumarins, they also are anticoagulants. Diphacinone, pindone, and chlorophacione belong to this group. Pindone was the first anticoagulant developed, and requires daily feeding to cause rodent death. Diphacinone will cause death after a single feeding. Both of these chemicals may induce bait shyness in rodents. Chlorophacione will also result in rodent death after a single feeding, and unlike most of the anticoagulants, does not cause bait shyness.

Benzenamines are chemicals that are not anticoagulants. The only rodenticide in this group is bromethelin (Vengeance®, Fastrac®, Gladiator®). These materials are particularly effective against Norway rats, roof rats, and house mice. When used with baits, rodents stop all feeding after a single dose, and death occurs shortly thereafter.

Cholecalciferol (Vitamin D_3) is the **active ingredient** in the rodenticides Quintox®, Rampage®, and Muritan®. These materials cause calcification of soft tissues, which can be fatal to rats after extended feeding. Cholcalciferol is used in baits and is tasteless. It is less toxic to humans than most rodenticides, but may poison small pets.

Some rodenticides are extremely dangerous to all mammals, including humans and their pets, and must be used with extreme care by applicators. Compound 1080, sodium fluoroacetate, is one of the most poisonous pesticides known. This material has gained considerable notoriety in connection with coyote control programs. Government **predator** control programs are now the only permitted use of Compound 1080.

Strychnine is a botanical rodenticide. It is highly toxic to all warm-blooded animals. It is somewhat commonly used for gopher and other underground pest control when pets and people are not present. Elsewhere it is rarely used because of its high toxicity and its relative poor performance as a rodenticide in comparison with anticoagulants.

Because people, rodents, and many domestic animals and pets are closely related genetically, rodenticides have a high potential for accidental poisoning. This danger can be minimized by use of protected bait boxes, and as always, usage in strict compliance with the pesticide label.

PESTICIDE FORMULATION

Using pesticide **formulation**s are another way to classify pesticides. Pesticides are nearly always applied in formulations containing other materials. This is true by almost all types of pesticides. Unformulated pesticides are referred to as **technical grade**, and these are used only by toxicologists and other pesticide chemists or biologists conducting tests on pesticide resistance or susceptibility to target and non-target organisms. Technical grade pesticides are either formulated by manufacturers or by commercial pesticide distributors. All formulations sold in the USA must be labeled with complete instructions and restrictions for use. One formulation of a pesticide may be legally applied for a certain purpose, but a different formulation of the same pesticide may not be. That is why it is critical to completely read and understand the label for all pesticide formulations, especially if an applicator is using it for the first time.

Formulation is done to improve safety, ease of handling, storage, ease of use, and effectiveness of pesticides.

Formulations are nearly always the form in which pesticides are obtained by vector control specialists, and it is the formulation that must be registered, have an EPA registration number, a label, and a Material Safety Data Sheet. The formulation of any pesticide is identified by a letter or letter combination on the label.

Formulations may undergo a final dilution with water or other **diluent** after being added to a spray tank or similar device. This is not considered formulation, and this final form is usually called the tank mix.

Some of the most commonly used formulations are:

Emulsifiable Concentrates (EC)

These chemicals consist of concentrated oil **solutions** of technical grade pesticides combined with an **emulsifier** added to permit further mixing with water. Emulsifiers are detergent-like materials that allow the **suspension** of very small oil droplets in water to form an **emulsion**. **Emulsifiable concentrates** are used widely in vector control operations, with final water dilutions typically being made in spray tanks. Tank mixes are usually milky in appearance. ECs are losing popularity somewhat with the rise in costs of petroleum products, and new formulations using plant-derived oils are being sought.

Wettable Powders (WP or W)

These dispersible powders are finely ground, dry powders consisting of active pesticide ingredients mixed with other ingredients to aid in mixing and dispersion. **Wettable powders** are intended for mixture with a liquid, usually water, for application by spray equipment. They are generally mixed with water to form a **slurry** before being added to the spray tank. In the tank they require continual agitation. WPs can be used for most pest problems and in most spray equipment. Bti is available as a WP. WPs are harder on equipment than some other formulations, and can cause rapid wear on pumps, gaskets, and spray nozzles.

Soluble Powder (SP)

These powders are similar to **wettable powders,** except that the active ingredient, as well as the diluent and all formulating ingredients are completely **soluble** in water. Uses of **soluble powders** are similar to those of wettable powders.

Dusts (D)

Pesticides formulated as **dusts** are finely ground mixtures of **active ingredient** and a carrier material. **Dust formulation**s are intended for direct application without further mixing. Dusts are never used where drift is a potential problem. For this reason, herbicides are not formulated as dusts. In vector control, dusts are frequently used to control fleas and other ectoparasites on pets. They are also applied to rodent burrows and bait stations to control fleas in plague control operations.

Granules (G)

In a granulated **formulation**, the **active ingredient** is mixed with various inert clays to form particles of various sizes. Granules used in vector control operations are usually from 20 to 80 mesh in size. Granular formulations are intended for direct application without further dilution. Granular formulations require specialized dispersal equipment, and may be applied from the air or on the ground. They may be used with small hand-cranked units, or simply scattered by hand (with appropriate personal protection). Granular applications of pesticides are especially useful in treating mosquito larvae in locations where heavy vegetation would otherwise prevent the insecticide from reaching the water. They are also favored in situations where drift would otherwise be a problem.

Fumigants

Fumigants are volatile chemicals stored as liquids under pressure, or incorporated into a solid form with clay which releases toxic gas when combined with water **vapor**. The only vector-related uses of fumigants are for treating rodents and their associated ectoparasites underground. Fumigants are used for structural pest control and may include species that are considered vectors (e.g., cockroaches). Mothballs are fumigants.

Baits

Baits contain active ingredients that are mixed with a pest food or attractant. Principal uses include control of household pests such as ants, mice, rats, roaches, and flies; they are used outdoors to control birds, ants, slugs, snails, and agricultural pests such as crickets and grasshoppers.

Aerosols (A)

Aerosols, or "bug bombs" are pressurized cans which contain a small amount of pesticide that is driven through a small nozzle under pressure from an inert gas (called a **propellant**). Aerosols are often used in households. Organisms that may be killed using aerosols include weeds, flies, for a variety of greenhouse pests, and in structural pest control. The use of aerosols peaked during the 1990s before concerns for propellants consisting of chlorofluorocarbons were linked to damage to the ozone layer. Since then, aerosol can uses of all kinds have dropped significantly, although substitute propellants are continually being tested as replacements for chlorofluorocarbons.

Flowables (F or L)

A **flowable** liquid usually is mixed with water for use in a sprayer. It forms a suspension in water which requires continual agitation. Principal uses are similar to those of emulsifiable concentrates.

Water-Soluble Concentrate (WS)

These liquid **formulations** form true solutions in water and require no agitation once mixed. They are used in the same way as emulsifiable concentrates.

Ultra Low Volume Concentrates (ULV)

Ultra low volume concentrates (**ULV**) are sold as technical product in its original liquid form, or solid product dissolved in a small amount of solvent. They are applied using special aerial or ground equipment that produces a fine spray at very low application rates. Their main use in public health is as mosquito adulticides. The underlying principle of ULV is that an extremely small droplet of pesticide (~10-30 microns) is supposed to lethally strike a mosquito. Droplets that are larger are considered inefficient, wasteful, and can have undesirable environmental effects. ULV applications, when done correctly, are very effective and very safe to people and other non-target organisms.

Fogging Concentrates

Fogging concentrates combine a pesticide with a solvent, with the type of solvent depending upon the type of fogging to be done. These are formulations sold only for public health use to control flying insects such as flies and mosquitoes. These formulations are applied using special truck-mounted machines called **foggers**. Foggers are of two types: **thermal** foggers use flash heating of an oil solvent to produce a visible plume of vapor or smoke, and cold (ambient) foggers **atomize** a jet of liquid in a venturi tube under pressure from a high-velocity air stream. Cold foggers can use insecticides combined with oil, water, or emulsifying agents.

Slow Release or Controlled Release Formulations

Some insecticides can be encased (**encapsulated**) in an inert material for a controlled release, resulting in decreased **hazard** and increased likelihood of the active ingredient reaching the target organism. Sustained-release mosquito **larvicides** are based on this principle. Previous uses of this general method using resin strips impregnated with dichlorvos (DDVP), a volatile organophosphate insecticide, for fly and moth control, are no longer approved for use. The most successful vector control products are those that provide slow release of bio-pesticides, although some critics of this approach claim that this encourages physiological resistance on the part of the target pests.

Other Formulations

There are other **formulations** that could be mentioned here, some of them very important, such as the formulations for impregnating clothing, bed nets, and curtains in tropical areas of the world for malaria control. There are other formulations, such as oil solutions and soluble pellets that are found mostly on hardware store shelves for home and garden use. Novel formulations are being evaluated continually, and some of these will probably eventually be adopted for vector control use.

Chapter 3

PESTICIDE LABELS AND LABELING

The original 1947 FIFRA law required the registration and **labeling** of all **pesticide products** before being transported or sold in interstate commerce. With its amendment in 1972, this requirement was broadened to apply to pesticides transported in both interstate and intrastate commerce. Currently, pesticide registration and labeling is administered by the **EPA**. There are strict guidelines as to exactly what must appear on pesticide labels. It is very important for certified pesticide **applicators** to know what information all pesticide labels contain, and also that the use of a pesticide in any way not specifically listed on the label is prohibited, and that deliberate sales or uses of a pesticide in any way inconsistent with its label by a dealer or applicator is punishable by fine or prison, or both.

A pesticide label is a legal document. It contains information on how, when, and where the pesticide can be used. It lists **hazard**s to humans and domestic animals, and also lists any environmental hazards.

Every label contains a **signal word** – **DANGER**, WARNING, OR **CAUTION**, depending upon its toxicological classification. ALL pesticide labels contain the warning KEEP OUT OF REACH OF CHILDREN.

Labels and Labeling

The term **label** refers to the printed material attached to a pesticide container or a wrapper of a retail pesticide package. The term **labeling** refers to all of the printed instructions that come with a pesticide. This definition includes the label on the product, the brochures and flyers provided by the manufacturer, and other information, such as handouts, from the dealer.

Material Safety Data Sheets

For every pesticide there is also a document known as a Material Safety Data Sheet (**MSDS**). Whenever a pesticide is being applied, the operator must have in his possession sample labels and a MSDS for that pesticide. The MSDS contains information on the hazard from fire and explosion, health hazard data, reactivity data, and procedures required for environmental protection.

Determination of the signal word

The signal word is assigned based on the most severe toxicity category assigned to the five acute toxicity studies (Table 3.1). Furthermore, if methanol is present in a formulation at a concentration of 4% or more, the formulation is automatically to be assigned the signal word **DANGER**.

The signal word is required to appear on the front panel of all pesticide labels, as is the statement "KEEP OUT OF REACH OF CHILDREN" (KOOROC). The signal word and the KOOROC statement must not appear on the same line.

Reasons for Reading and Understanding Pesticide Labels

There are many reasons why anyone should be able to read and understand a pesticide **label**. The information contained on a label is there to provide safety to applicators, the public, and the environment, and to encourage the appropriate and effective use of the labeled pesticide. For the certified pesticide applicator there is a special reason for knowing all about pesticide labels. Passage of the Federal Environmental Pesticide Control Act (FEPCA) in 1972 resulted in the amendment of **FIFRA**. This amendment created the category of

restricted use pesticides and the requirement of certification of applicators of pesticides in this category. It stipulated that to be certified, applicators must be tested on (1) the general format and terminology of pesticide labels and labeling, (2) understanding of instructions, **warning**, terms, symbols, and other items of information typically appearing on labels, and (3) classification of the material (unclassified or restricted use), and (4) the necessity for uses consistent with the label. It should be noted not all public health pesticides are restricted use by EPA definition.

The Pesticide Product Label System

EPA dictates that manufacturers or formulators must produce labels for their registered products which contain certain information. This is of great help to those who must read labels, because a given piece of information concerning a pesticide will always appear on every pesticide label. The EPA maintains a database containing computerized images of approved pesticide labels. This information can be accessed on the Internet at http://www.epa.gov/pesticides/pestlabels. This information is part of EPA's Pesticide Product Label System, or PPLS. Pesticide labels approved by EPA are also available from manufacturers, formulators, and other commercial sources of pesticides, and often their websites are somewhat easier to use than those of EPA.

Table 3.1. Toxicity Categories for Pesticides

Study	Category I	Category II	Category III	Category IV
Acute Oral	Up to and including 50 mg/kg	> 50 thru 500 mg/kg	>500 thru 5,000 mg/kg	> 5,000 mg/kg
Acute Dermal	Up to and including 200 mg/kg	> 200 thru 2,000 mg/kg	> 2,000 thru 5,000 mg/kg	> 5,000 mg/kg
Acute Inhalation	Up to and including 0.05 mg/liter	> 0.05 thru 0.5 mg/kg	> 0.5 thru 2 mg/liter	> 2 mg/liter
Primary Eye Irritation	Corrosive (irreversible destruction of ocular tissue	Corneal involvement or other eye irritation clearing in 8-21 days	Corneal involvement or other eye irritation clearing in 7 days or less	Minimal effects clearing in less than 24 hours
Primary Skin Irritation	Corrosive (tissue destruction into the dermis and/or scarring	Severe irritation at 72 hours (severe erythema or edema)	Moderate irritation at 72 hours (moderate erythema)	Mild or slight irritation at 72 hours (no irritation or slight erythema
Signal Word	**DANGER/POISON**	**WARNING**	**CAUTION**	**CAUTION**

When Should You Read a Pesticide Label and the Material Safety Data Sheet?

There are five times when you should read the label and the MSDS.

1. Before you buy the pesticide: Is it the proper chemical for your job? Does the pesticide require special equipment or application techniques (which you may or may not have or know)? Do you have to have special qualifications to use the pesticide? Remember: do not buy the pesticide on the basis of reading only the brand name. Manufactures change products and formulations without changing brand names. You may not be buying what you think you are.

2. Before you transport, mix, or load the pesticide: Read the label to determine if any unusual precautions must be taken while transporting the product; how to mix the pesticide and how much to mix; what protective clothing and equipment are required; and what **first aid** procedures may be required in case of accidental exposure.

3. Before you apply the pesticide: Determine from the label when to apply the material, how to apply it, the rate of application, protective clothing and equipment required during application, and any residue and re-entry restrictions or disposal of crop residue restrictions which apply to its use.

4. Before you store the pesticide: Read the label to learn how to store the pesticide correctly. Pesticides should never be stored with food or feed. Many pesticides should not be stored where they may become contaminated by other pesticides. Many pesticides have heat and cold **recommendations**, or should not be exposed to UV radiation. The label will tell you if there are any special storage precautions to follow.

5. Before you dispose of unwanted pesticide or the empty container: Determine if the pesticide meets any of the criteria established by EPA for hazardous waste (See Chapter 10). If it does, read the label for instructions about the proper procedure for disposing of hazardous waste to avoid health risks or unwanted environmental contamination. Also read the label for information about the proper procedure for decontamination and disposal of the empty pesticide container. In addition to the pesticide label there are many other sources of information concerning hazardous waste management. Most information is available from either EPA or the DPR Even if the pesticide is not considered hazardous waste, you should use common sense in preparing pesticides or pesticide containers for disposal.

FORMATS FOR PESTICIDE LABELS

EPA has suggested formats for pesticide labels. With only minor differences, the formats are the same for both unclassified pesticides and restricted use pesticides. EPA requires the following information in approximately the following order:

Front Panel

1. Restricted Use Pesticide Statement (if applicable).
2. Product Name, Brand, or Trademark.
3. Ingredient Statement.
4. Keep Out of Reach of Children (KOOROC) Statement.
5. Signal Word. **DANGER/POISON** (Toxicity Category I), **WARNING** (Toxicity Category II), or **CAUTION** (Toxicity Category III). Not required for Toxicity Category IV.
6. First Aid.
7. Skull & Crossbones Symbol and the word "POISON" prominently in red on a background of distinctly contrasting

color. <u>This requirement applies to pesticides in Toxicity Category I where the toxicity determination is based on **oral**, **inhalation**, or **dermal toxicity** as opposed to skin or eye irritation.</u>

8. Net Contents/Net Weight.

Front or Back Panel

1. EPA Registration Number and Establishment Number. <u>The EPA Registration Number is the single most important piece of information for tracking pesticide products and its appearance on each pesticide label is an absolute requirement.</u>

2. Company Name & Address.

Back Panel

1. Precautionary Statements.

    a. Hazards to humans and domestic animals.

    b. First aid.

    c. Environmental hazards.

    d. Physical or chemical hazards.

2. Directions for use.

3. Storage and disposal.

4. Worker protection **labeling**.

A sample label for pesticides in each category is contained in Figures 3-1 and 3-2.

THE CHANGING NATURE OF PESTICIDE LABELS

By the time you are reading this, there will probably have been numerous changes to labeling requirements for pesticides made by federal and state agencies. Some of these will have resulted from changes in federal and state laws, others by changes made by EPA and others as a result of new scientific information becoming available on various pesticides. It is difficult to keep training manuals such as this one entirely accurate because of these changes. Fortunately, the Internet contains a wealth of information on pesticides. If you are in doubt as to which pesticides are on either the federal or California list of restricted pesticides, this information can be found on either the website of EPA (http://www.epa.gov/) or the DPR (http://www.cdpr.ca.gov/). The latter website in particular is updated frequently.

Some of these changes may be minor, and may not affect public health uses. Others may result from the failure of a pesticide to be reregistered and the registrations of some pesticides may be suspended after critical government review. Because of the rapidly changing landscape of pesticide registration it is vital that all pesticide applicators keep their training current, and that they be alert to bulletins and other information on pesticide changes.

RESTRICTED USE PESTICIDE

ACUTE TOXICITY and GROUND WATER CONTAMINATION

For retail sale to and use only by Certified Applicators or persons under the direct supervision of a Certified Applicator, and only for those uses covered by the Certified Applicator's certification.

Bayer CropScience

TEMIK® brand 15G Lock 'n Load®

ALDICARB PESTICIDE

CLOSED HANDLING SYSTEM

For Control of Certain Insects, Mites, and Nematodes

ACTIVE INGREDIENT: Aldicarb [2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl)oxime] **15%**
INERT INGREDIENTS: **85%**

EPA Reg. No. 264-330 **EPA Est. No. 264-GA-01**

KEEP OUT OF REACH OF CHILDREN

DANGER POISON

PELIGRO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle.
(If you do not understand the label, find someone to explain it to you in detail.)

For MEDICAL And TRANSPORTATION Emergencies ONLY Call 24 Hours A Day 1-800-334-7577
For PRODUCT USE Information Call 1-866-99BAYER (1-866-992-2937)

FIRST AID

IF SWALLOWED:	• Immediately call a poison control center or doctor for treatment advice. • Do not induce vomiting unless told to do so by a poison control center or doctor. • Have person sip a glass of water if able to swallow. • Do not give anything by mouth to an unconscious person.
IF IN EYES:	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing. • Call a poison control center or doctor for treatment advice.
IF ON SKIN OR CLOTHING:	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a poison control center or doctor for treatment advice.
IF INHALED:	• Move person to fresh air. • If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably mouth-to-mouth if possible. • Call a poison control center or doctor for further treatment advice.

For MEDICAL Emergencies Call 24 Hours A Day 1-800-334-7577.
Have the product container or label with you when calling a poison control center or doctor or going for treatment.

Aldicarb is a N-methyl carbamate.

1

Fig. 3.1 The Label for Temik® (aldicarb), a restricted-use pesticide

Altosid® PRO–G

INSECT GROWTH REGULATOR

PREVENTS ADULT MOSQUITO EMERGENCE ***(including those which may transmit West Nile virus)***

PREVENTS MOSQUITOES FROM BECOMING BREEDING, BITING ADULTS

30 DAY PROTECTION

EASY TO APPLY GRANULES

TREATS UP TO 5,445 SQUARE FEET OR 20,183 GALLONS OF WATER

SPECIMEN LABEL

ACTIVE INGREDIENT:

(S)-Methoprene (CAS #65733-16-6)	1.5%
OTHER INGREDIENTS:	98.5%
Total . . .	100.0%

EPA Reg No. 2724-451

KEEP OUT OF REACH OF CHILDREN

CAUTION

PRECAUTIONARY STATEMENTS HAZARDS TO HUMANS AND DOMESTIC ANIMALS CAUTION

Causes moderate eye irritation. Harmful if absorbed through skin. Avoid contact with eyes or skin. Due to the size and abrasiveness of the granule, use protective eyewear and clothing to minimize exposure during loading and handling. Wash thoroughly with soap and water after handling.

FIRST AID	
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye.
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes.
Call a poison control center or doctor for treatment advice. Have the product container or label with you when calling a poison control center or doctor, or going for treatment. You may also contact 1-800-248-7763 for emergency medical treatment information.	

ENVIRONMENTAL HAZARDS

Do not contaminate water when disposing of rinsate or equipment washwaters.

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling.

GENERAL DIRECTIONS

Zoecon® Altosid® Pro-G Insect Growth Regulator (Altosid Pro-G) releases effective levels of **ALTOSID®** insect growth regulator for up to 30 days after application. Applications should be continued throughout the entire season to maintain adequate control. Treated larvae continue to develop normally to the pupal stage where they die.

Apply **Altosid Pro-G** uniformly and repeat application as necessary. Measure and then sprinkle the appropriate amount of **Altosid Pro-G** evenly over the surface of the water to be treated in order to control mosquitoes before they become breeding, biting adults. Measure the surface area of the water and follow the table below for the appropriate amount of product to use. Emptying or discarding small containers that are holding water will ensure the best results. In instances where small containers cannot be emptied or discarded and for locations such as flower pots, old tires, urns, etc. use approximately 80 granules for every gallon of water.

Fig. 3.2 The label for Altosid ® (methoprene), an unclassified biopesticide

Chapter 4

TOXICITY OF PESTICIDES TO HUMANS

Toxicology is the science of **poisons**. Paracelsus, who lived from 1493 to 1541, wrote: "All substances are poisons; there is none which is not a poison. The right **dose** differentiates a poison and a remedy." Paracelsus was right. Few substances that can be absorbed through the skin, inhaled, or **ingested** are truly inert. Many substances that are harmless or even beneficial in limited quantities or with some **exposure** routes could be considered poison via an alternative exposure route. For example: Thousands of gallons of water are harmless when swimming in them for an hour, but if you consume as little as two gallons of water in that same hour, the water becomes a toxic poison that will probably kill you. Salt that seasons your food becomes a poison if taken in excessive quantities. Even oxygen, which is a necessity of life, becomes toxic at extreme concentrations. It has been said: "There are no harmless substances. There are only harmless ways of using substances." This is generally true and a very important concept.

Pesticides are poisons. If they were not, they could not be effective in controlling pests. However, generally pesticides are far more poisonous to pests than they are to humans or domestic animals. Pesticides vary greatly in the toxicity hazard they represent to humans and domestic animals. Generally, modern vector control operations emphasize the use of pesticides that are the least **hazard**ous to **non-target organisms** and regulatory agencies place great stress on means of reducing human hazards to pesticides. Data from poison control centers in the USA show that deaths resulting from poisonings from pesticide exposure represent a relatively small proportion of the total number of poison-related deaths. Nevertheless, each year some pesticide-related poisonings do occur in the USA, and some have major medical consequences, including death. Because of this, it is essential that everyone involved in pesticide use understand the principles of pesticide poisoning, and the role of safe use of pesticides in avoiding poisoning incidents.

PESTICIDE TOXICITY AND HAZARDS

In terms of pesticide safety, there is an important difference between the words "**toxicity**" and "**hazard**". Toxicity refers to inherent poisonous **potency** of a material. Its toxicity is evaluated in toxicology laboratories and is always expressed in quantitative terms such as **LC_{50}** (**lethal** concentration-50, the concentration at which a material will kill 50% of some reference **organism**. Hazard, on the other hand, depends not only on the toxicity of a material, but also on the risk of toxic exposure when used. In simple terms, remember that toxicity is the capacity of a substance to produce illness or death, hazard is a function of toxicity and exposure. Together, toxicity and hazard information can be used to determine risk.

There is a greater potential for harmful effects to humans from highly toxic pesticides than from pesticides that are less toxic. However, the concentration of the pesticide in a formulation, the length of human exposure to a pesticide, and the route of entry into the human body are equally important in the potential for poisoning. Although a pesticide **applicator** will have little control over the toxicity of a pesticide, he or she will have significant control over hazards associated with pesticide use. A sealed container of a very toxic pesticide presents little hazard to a pesticide technician before the seal is broken. Even when the container is opened, the hazard (or risk?) may be small if the technician is wearing protective clothing, gloves, and eye protection. However, if the container is leaking, or if the technician is not using **protective gear**, the hazard can be high.

TYPES OF TOXICITY

Toxic effects can range from slight **symptoms** like minor skin irritation or hay-fever like symptoms to headaches or nausea. **Organophosphate** pesticides and some **herbicide**s can cause severe symptoms like convulsions, coma, possibly even death. Pesticide toxicity in humans can be classified by the nature of exposure, by the route by which exposure occurs, or by the body function or system affected. Generally, any poison is more toxic if ingested by mouth than if inhaled, and more toxic if inhaled than if by **dermal** (skin) exposure.

Poisons work by altering normal body systems or functions. Thus, toxicity can occur in as many ways as there are body functions. Poisons can affect just one particular organ system or they may produce generalized toxicity by affecting a number of systems.

Some toxic effects are quickly **reversible** and do not cause permanent damage. Others may cause reversible damage, but complete recovery may take a long time. Still other poisons may cause irreversible damage, even if the exposure is not fatal.

CLASSIFICATION BY TYPE OF EXPOSURE

Toxicity may be divided into four types, based on the number of exposures to a poison and the time it takes for toxic symptoms to develop. These four types may be combined with the classification based on route of exposure discussed below.

Acute Toxicity

When a person is exposed to a single dose of a pesticide, it is referred to as an "**acute**" exposure. Further, if the exposure is by contact with skin, it would be regarded as an **acute dermal** exposure. **Acute oral** refers to a single dose taken by mouth, and **acute inhalation** refers to a single dose that is inhaled.

Chronic Exposure

When there is repeated or continuous exposure to a pesticide by a person, it is called "chronic" exposure. This toxicity can be described in terms of chronic dermal, chronic oral, or chronic **inhalation toxicity**.

Subchronic Exposure

When there has been repeated or continuous exposure to a pesticide, but no measurable toxic affects have resulted, a person is said to have been subjected to "subchronic" exposure.

Delayed Toxicity

Delayed toxicity may occur many years after exposure to a chemical and is most often only discovered in retrospective **epidemiological** studies (studies done after the fact). Some chemicals that produce delayed toxicity are fipronil and asbestos. Epidemiological studies are crucial to the detection of further occurrences of delayed toxicity.

CLASSIFICATION BY BODY SYSTEM AFFECTED

Cutaneous Toxicity

Cutaneous toxic reactions are most often associated with petroleum based **products**, pyrethroids, and some herbicides. These reactions account for approximately one-third of all pesticide-related occupational illnesses. Dermatitis is the term used to describe any skin rash associated with inflammation and redness. There are many different types of dermatitis — they differ in appearance and in how they are caused. Among agricultural workers, dermatitis may be caused by exposure to non-work related irritants or to crops, plants, or pesticides. Cutaneous toxicity can be further categorized by specific response of the skin.

Primary irritant dermatitis (PID). This type of dermatitis is caused by chemical substances that directly irritate the skin (such as acids or bases). PID effects may be relatively minor with only minor irritation or may be very severe, with blisters or ulcerations. Areas directly contacted by the irritant are usually most severely affected.

Herbicides are the pesticides that most frequently cause PID. Few herbicides causing PID are used in vector control, with the exception of refined petroleum products, or **formulations** that use refined petroleum as a **carrier**. Exposure to pyrethroids can cause a crawling or tingling sensation in the skin, and may irritate mucus membranes.

Allergic contact dermatitis (ACD). This type of dermatitis is caused by chemical substances that stimulate development of an allergic reaction. Workers may handle an allergenic substance for years
ACD develops, or it may develop after a single exposure. Symptoms vary from redness and itching to large painful blisters. Naled and malathion e
may result in ACD.

CLASSIFICATION BY ROUTE OF ENTRY

There are four common ways in which pesticides can enter the human body: through the skin, the mouth, the lungs, and the eyes.

The chances of pesticide entry into the body is affected by the state of the chemical, i.e., as a solid, liquid, or gas. Liquids or gasses can penetrate the body via any of the four routes. Solids tend to have a lower chance of entry through the lungs or eyes, but if solid particles are small enough or if they remain on the skin long enough, entry is possible in the same ways that liquids or gasses can enter.

Dermal Exposure

Absorption through the skin is the most common route by which pesticide applicators are poisoned by pesticides and other chemicals. **Dermal** absorption may occur as a result of a splash, spill, or **drift** when mixing, loading or disposing of pesticides. It may also result from exposure to large amounts of **residue**. The degree of dermal absorption hazard depends on the **dermal toxicity** of the pesticide, the extent of the exposure, the way the pesticide is formulated, and the part of the body contaminated. In general, **wettable powders**, **dusts,** and **granular pesticide**s are not as readily absorbed through the skin and other body tissues as are the liquid formulations such as the **emulsifiable concentrates,** which contain a high percentage of the **toxicant** in a relatively small amount of solvent. Certain areas of the body, such as the male scrotum, are more **susceptible** to pesticide absorption than other areas of the body.

DON'T TAKE CHANCES: IF YOU BECOME CONTAMINATED, WASH IMMEDIATELY!

Oral Exposure

If enough pesticide gets into the mouth, it may cause serious illness, severe injury, or even death. Pesticides may be consumed through carelessness or they may be consumed by individuals who are intent on personal harm. The most frequent cases of accidental oral exposure are those in which pesticides have been transferred from their original labeled container to an unlabeled bottle or food container, frequently by someone other than the person who is eventually poisoned. There are many cases where people, especially children, have been poisoned drinking pesticides from a soft drink bottle. In other cases, people have been poisoned after drinking water stored in pesticide-contaminated bottles.

Respiratory Exposure

Pesticides are sometimes inhaled in sufficient amounts to cause serious damage to nose, throat, and lung tissues. The hazard of respiratory exposure is great because of the potentially rapid **absorption** of pesticides through this route. **Vapors** and extremely fine particles have the greatest potential for poisoning via respiratory exposure.

Pesticide exposure is usually relatively low when **dilute** sprays are being applied with conventional application equipment because larger droplet sizes are produced. When low volume equipment is being used to apply concentrated material, the potential for a respiratory exposure is increased because smaller droplets are being produced. Application in confined spaces also contributes to increased potential for respiratory exposure. **Respirators** and **gas mask**s can provide protection from **respiratory** exposure.

Eye Exposure

Eyes are particularly absorbent, and therefore getting any pesticide in the eye presents an immediate threat of blindness, illness, or even death. Eye protection is always needed when measuring or mixing concentrated and highly toxic pesticides. Eye protection also should be used when there is a risk of exposure to dilute spray or dusts that may drift into the eyes. Granular pesticides may present a special hazard to eyes because of the size and weight of the individual particles. If applied with power equipment pellets may bounce off vegetation or other surfaces at high velocity and cause significant eye damage as well as poisoning to an applicator if struck in the eye. Protective shields or goggles should be used whenever there is any chance of pesticides coming into contact with the eyes.

TOXICITY TESTING AND MEASUREMENT

Modern analytical methodologies have made it possible to test for minute amounts of pesticide – in some instanced down to the parts per trillion (ppt) level. Expression like parts per million (ppm) are usually used to describe very dilute concentrations of something, typically in soil or water. Nevertheless, their use in measurements of various **pollutants** in water and soil are well entrenched in the USA, and their use will probably continue for years to come.

A concentration of 1 ppm of a liquid **insecticide** in water would represent 1 microliliter of some product in 1 liter of water, or in shorthand, 1 µl/liter. Because not everyone understands the units involved in analyses of pesticide residues in soil and water it is useful to understand these units in everyday terms. **One part per million** would be the equivalent of a drop of a liquid pollutant in about 13 gallons of water. **One part per billion** would be the equivalent of about one drop of a liquid pollutant in 250 chemical 55-gallon drums. **One part per trillion** would be the equivalent of about one drop of a liquid pollutant in 20 Olympic-sized 6-foot-deep swimming pools. As can be seen by these illustrations, the amount of pesticide detectible in samples of various types is extremely small. Another way of looking at this would be to say the modern chemical detection methods are extremely **sensitive**.

TOXICITY TESTING IN EXPERIMENTAL ANIMALS

Because testing of poisons on humans is not only unethical, but also illegal, potential human effects are estimated by testing on tissue of various other species of animals, usually **mammals**. Because modern society seeks to avoid unnecessary testing using animal subjects and testing that exposes animals to needless discomfort, such tests are rigorously monitored to be done in the most humane way possible. The results of this animal testing are submitted to **EPA** and other agencies as a requirement for registration of a pesticide formulation. These test results are used to establish the toxicity category for pesticide **formulations** and also for the preparation of material safety data sheets to provide information on recommendations of things such as **first aid**, necessary protective devices, **antidotes**, and handling procedures for pesticides. For poisons, there is always a large safety factor included (effects of any particular dose are overestimated) to account for possible differences between the effects observed in the animal subject and potential effects to humans.

DOSE-EFFECT RELATIONSHIPS

In tests of pesticides to determine toxicity, some accounting for variation of effects on individual test animals must be done to establish a single value for toxicity. The alternative to this would be to report a range of values for a given test. For example, if a test was to be performed on rabbits to estimate the dermal irritation effect on human skin for a new **insect repellent**, the technician would have to report that at a dose of 1 mg per cm^3 of skin, between 16 and 37 rabbits per 100 tested showed evidence of skin irritation. This information would not be very useful. Rather, better and more useful data are obtained if a series of doses are tested against a group of test animals. A concentration can then be calculated at which some pre-defined effect occurs in half of each group of test subjects. This dose is called the **effective dose 50**, and is written **ED_{50}**. If death is the effect being measured the expression **lethal dose 50** or **LD_{50}** is used. In some pesticide tests, toxicologists may be more interested in the dose at which 80% or 90% of the test subjects are affected. In these cases, the expressions ED_{80} and ED_{90} would be used, respectively.

Terms Related to Dose-Effect Relationships

The highest dose that results in no observable change in 50% of a test population is the **no observable effect level** (**NOEL**). This expression will be encountered frequently in pesticide reports and other documents. The **Toxic Dose** (**TD**) is used to indicate the dose that will produce signs of toxicity in a certain percentage of a species of animals. The **TD_{50}** is calculated in the same manner as ED_{50} and LD_{50}, but the expressions mean very different things, and will not always bear the same relationships to one another. For example, an LD_{50} value for a given chemical will furnish no information on possible non-lethal toxic effects.

The standard units used to describe dosage in pesticide tests is mg/kg of body weight. It should be remembered that **the smaller the number, the more toxic the chemical tested**. A chemical with a small LD_{50} (such as 5 mg/kg) is very dangerous. A chemical with a large LD_{50} (1,000 to 5,000 mg/kg) is not very dangerous.

Another expression used in connection with toxicity testing is the lethal concentration 50, or **LC_{50}**. This is usually used for exposures of pesticides in the vapor state, such as **fumigant**s.

TOXICITY TESTING REQUIRED FOR REGISTRATION

Before a pesticide can be released for sale it must go through a process known as **risk assessment**. This is the process by which the various toxicity categories are assigned to pesticide **formulations**. The basic risk assessment consists of four steps:

1. Hazard identification.
2. Dose-response assessment.
3. Exposure assessment.
4. Risk characterization.

The **hazard identification** is based on the toxicity of a given product based on acute and chronic toxicity tests performed with experimental animals. The **dose-response assessment** is explained above. These are the tests performed at different dose levels on groups of experimental animals to obtain ED_{50} and LD_{50} numbers. The **exposure assessment** is based on the proposed use of a pesticide formulation and the probability of exposure to applicators, other workers, children, and the general public. The **risk characterization** is based on combining the hazard identification and exposure results. This is a simple explanation of a very complex and drawn-out process.

Because there are many possible effects chemicals can have on humans and domestic animals in addition to acute responses leading to severe illness and death, toxicity tests of new pesticides include tests for such things as birth defects in offspring (teratogenesis), cancers and **tumors** (**carcinogenesis**), and many other chronic effects. Although tests are performed on experimental animals, the test results and their interpretation are based on the premise that effects on experimental animals can be used to estimate effects on humans. To make the tests as reliable as possible for estimating possible human risks, a variety of animals species often are used in toxicity tests.

GROUPS OF VERTEBRATE TOXICITY TESTS

Candidate pesticides may go through as many as six groups of tests in order to establish toxicity levels. These groups are **Acute Toxicity** (oral, dermal, inhalation, eye, and others), **Subchronic toxicity**, **Chronic toxicity**, **Genetic toxicity**, **Neurotoxicity**, and **Special studies** (companion animal toxicity, **metabolism**, dermal penetration, and immunotoxicity).

Acute Toxicity Studies

A candidate pesticide first must undergo a series of acute toxicity studies. Test animals are given various amounts of the chemical in either one oral dose or by a single **injection**. The animals are then observed for 145 days. The test often determines the candidate pesticide's LD_{50}.

From this test, an estimate is made of the dose of the chemical which will kill 10% of the animals (LD_{10}). The LD_{10} is then used as the highest dose in a 14-day repeated dose study. At the end of this test, the animals are sacrificed and necropsied (i.e., their bodies are examined) for any evidence of toxic effects. The purpose of the repeated dose study is to establish the highest dose of the chemical that does not produce any signs of short-term toxicity.

Subchronic Toxicity Studies

The subchronic toxicity study is the next testing step. This is carried out for a period of 90–150 days. The highest dose tested during the subchronic study is the dose that was found to produce no signs of toxicity in the earlier 14-day study. Lower doses are also tested.

During this study, the animals are observed closely to see if they develop any signs of toxicity. At the end of the study period, they are necropsied, and based on the findings, a **maximum tolerated dose**

(**MTD**) is selected. The MTD is the highest dose of the chemical that does not have an effect on the life span of the animals tested. The MTD should not have any severely detrimental effects on the animals' health. The MTD must be established before the chronic toxicity studies are done.

Chronic Toxicity Studies

Carcinogenesis and **oncogenesis** both mean the production of tumors. The term tumor, cancer, and neoplasm are all used to mean an uncontrolled growth of cells. There are many different cancers recognized. Some are considered malignant (potentially lethal), others benign (cause little harm).

Carcinogenic or **oncogenic** substances are substances that can cause the production of tumors. Some chemical examples are vinyl chloride, asbestos, and cigarette smoke. Carcinogenesis testing is probably the most expensive aspect of toxicity testing. These kinds of studies typically take from 18 months to two years to complete. During carcinogenesis testing, the highest dose of the chemical given is the MTD. It is administered to the animals each day using the same route of exposure that would occur in humans. The animals are carefully monitored throughout the entire study.

Necropsies are done on all study animals, either as they die or at the end of the study. The organs are examined microscopically for tumors or signs of pre-tumorous tissue changes.

Four criteria are used and accepted as evidence of **carcinogenicity**:

1. Tumors occur more frequently in treated animals than in untreated ones (**controls**).
2. Tumors occur sooner in treated animals than in untreated ones.
3. Treated animals develop different types of tumors than untreated ones.
4. Tumors occur in greater numbers in treated animals than in untreated ones.

If a candidate chemical being tested satisfies any one of these four criteria, it is considered to be a potential **carcinogen**.

Teratogenesis

A teratogen is any agent causing a change in the structure or function of the offspring of an animal resulting from exposure of the fetus. The process is called teratogenesis. An example of a chemical teratogen is thalidomide. Measles virus infection during pregnancy also has teratogenic effects. Teratogenesis affects the normal development of the embryo or fetus, but not the genetic makeup of the offspring. Thus, teratogenic effects are limited to the offspring, and are not passed on to future generations.

Teratogenesis studies of new chemicals generally are carried out in three phrases in mice, rabbits, and rats. In some tests, both male and females animals are exposed to a test chemical before mating; in other tests pregnant females are exposed at various stages of pregnancy. Either fetuses or newborn animals are examined for evidence of abnormalities.

Mutagenesis

Changes in genetic structure of animals are called **mutations**, and agents that cause mutation are called mutagens. The change in genetic structure of animals is mutagenesis. Many oncogens (carcinogens) are mutagenic and many mutagens are oncogenic. Mutagenic effects are not limited to the offspring and are passed on to future generations. In order for mutagenic effects to be passed on, they must occur in reproductive cells. Thus mutagenesis is a type of reproductive toxicity.

Mutagenicity testing can be used to predict whether or not a chemical might cause genetic alterations in people. This testing cannot be done directly, but relies on many tests done with **bacteria**, cell cultures, and animals.

Reproductive Toxicity

Chemical effects on reproduction are tested by exposing male and female rats to the chemical. The rats are then mated and the number of offspring recorded. If the test chemical has a harmful effect on fertility, it will decrease the number of offspring produced. Other tests can then be done to find out if the chemical affects males, females, or both.

Special studies

Occasionally, observations made during standard acute and chronic toxicity testing indicate that special studies are needed to further explore unusual types of toxicity. For example, if the test animals appear to be behaving strangely, behavioral studies may be done to examine the problem. A chemical may produce only slight depression and drowsiness without other evidence of toxicity. However, these effects can be extremely hazardous in situations where a person has to work with dangerous equipment, and behavioral toxicity is especially important in industrial toxicology.

HOW PESTICIDES AFFECT HUMANS

The exact way that pesticide poisoning can affect humans, and the degree to which certain segments of the human population can be affected are not completely understood. However, the signs and symptoms of acute pesticide poisoning are well known. **Symptoms** are what a person feels and can express to others. **Signs** are things one person can observe in another person, even if that person is unconscious. Pain and nausea are symptoms. Redness of skin, swelling, and hot, dry skin are signs. You should learn and be alert to the signs and symptoms of the early stages of poisoning. If any sign of poisoning develops, you should immediately and completely remove the source of exposure. By doing so, you may prevent additional exposure and minimize injury. **Early recognition of the signs and symptoms of pesticide poisoning, and immediate and complete removal of the source of exposure may save a person's life. This is especially critical if the person is unconscious, or otherwise unable to communicate clearly.**

However, remember that the signs and symptoms of pesticide poisoning can also be caused by other factors, such as infectious diseases or exposure to other chemicals. Therefore, it cannot be assumed that because an individual is in the vicinity of pesticides or a pesticide application, the development of some signs or symptoms of poisoning are necessarily the result of pesticide exposure. Nevertheless, if any signs or symptoms appear after contact with pesticides, you should contact a physician for assistance *without delay*. If there is any doubt as to the cause of the signs you observe, take the safe course of action. No one will ever criticize you if you seek medical attention for a fellow worker who may have been poisoned and it turns out that he or she has not been.

SYMPTOMS OF PESTICIDE POISONING

Organophosphate, **carbamate**, and organochlorine pesticide use has dramatically declined or been eliminated in vector control operations in California. However, because some products with a high potential for human poisoning fall into these groups, the signs and symptoms associated with poisoning should be well known to pesticide applicators.

ORGANOPHOSPHATE PESTICIDES

Organophosphate poisons attach themselves to a chemical in the blood that is normally present and necessary for proper nerve functioning. This chemical is the enzyme **cholinesterase**. The organophosphate pesticides bind to the enzyme and make it unavailable to the nerve connections. When cholinesterase is unable to perform its normal function, the nerves in the body fail to send messages to the muscles properly. In such cases, the muscles may receive continuous or erratic stimulation, leading to twitching, tremors, or constant contractions (tetany). If the muscle action becomes intense, the victim may suffer convulsions. In cases of severe poisoning, quick and proper medical treatment may reverse the effects of the poisoning, and the life of a person can be saved even in advanced states of poisoning. For the stages of poisoning of organophosphates and carbamates, refer to Table 4.1.

CARBAMATE PESTICIDES

The **mode of action** of carbamates is similar to that of organophosphates, and they also inhibit the enzyme cholinesterase. The signs and symptoms of carbamate poisoning are essentially the same as those caused by the organophosphates, but carbamates are broken down relatively rapidly in the human body. Consequently, the effect of carbamates on cholinesterase inhibition is relatively brief. Because of this, blood tests on cholinesterase in people suspected of pesticide poisoning may not be an accurate indication of carbamate poisoning.

BLOOD TESTS FOR OPERATORS

California regulations require medical supervision of workers whose duties expose them to pesticides known to have the potential to inhibit blood cholinesterase levels, i.e., organophosphates and carbamates. The details of this supervision are contained in Section 6728 of the California Code of Regulations. The enforcement of this program is the responsibility of the DPR, whose pesticide safety program is widely considered to be the best and most stringent in the nation. The details of this supervision are important, and are contained in their entirety in Appendix 1.

ORGANOCHORINE PESTICIDES

No compounds in this group are currently registered for public health uses in California. The **organochlorines** act on the central nervous system. Many of these compounds and their **degradation** products can be stored in the fatty tissues as a result of either large single doses or repeated small doses. Single large doses can cause liver and kidney damage in animals. Symptoms of organochlorine pesticide poisoning include nervousness, nausea, and diarrhea. Heavy doses may lead to convulsions or other central nervous system impairment.

BOTANICAL PESTICIDES

Pesticides derived from plants vary greatly in their chemical structure and also in their toxicity to humans. The toxicity of these pesticides ranges from pyrethrum, which is one of the least toxic of all insecticides to mammals, to strychnine, which is one of the most toxic

PYRETHRUM

Pyrethrum is a natural **botanical pesticide** containing the **active ingredient pyrethrin**. These pesticides are among the least toxic to mammals (LD_{50} in rats about 1,500 mg/kg).

STRYCHNINE

Strychnine is an alkaloid that will kill a wide variety of vertebrates and invertebrates. Strychnine is rarely used because of the potential for non-target and secondary effects. Strychnine is not currently used for vector control. It is registered in some states, including California for mole and gopher control. It has an LD_{50} in rats of about 1-30 mg/kg. It is included here for comparison with pyrethrum, another botanical pesticide.

PYRETHROID PESTICIDES

These are synthetic pesticides with chemical structures similar to pyrethrins. Because of this they are called pyrethroids, or pyrethrum-like. Pyrethroids exhibit a wide range of toxicity, from very low (permethrin, LD_{50} in rats >4,000 mg/kg) to very high (tau-fluvalenate, LD_{50} in rats 261 mg/kg). Pyrethroids used in public health applications include permethrin, resmethrin, sumithrin, cypermethrin, cyfluthrin, deltamethrin, lambda-cyhalothrin, and others. However, in aquatic environments, these materials can be considered very toxic to fish and other organisms. In EPA toxicity tests 96-hour $\mathbf{LC_{50}}$ values of <1 µg/liter have been found for some organisms. Resource agencies will usually use these very low values when establishing relative-risk evaluations for pesticides or other chemicals.

FUMIGATION MATERIALS

The only material considered a fumigant used in vector control is zinc phosphide, a **rodenticide**. Chloropicrin is used as a **soil fumigant** to kill soil insect pests, and aluminum phosphide is used to control stored grain insects. All fumigants are extremely toxic when inhaled, but those listed above have no **dermal** toxicity, and are very easy to work with when wearing appropriate safety equipment – a cartridge respirator and eye protection.

Table 4.1. Signs and Symptoms of Organophosphate / Carbamate Poisoning

Mild Poisoning	Moderate Poisoning	Severe Poisoning
Fatigue	Unable to walk	Unconsciousness
Headache	Weakness	Severe restriction of eye pupil
Dizziness	Chest discomfort	Muscle twitching
Blurred vision	Constriction of eye pupil	Secretions from nose and mouth
Excessive sweating and salivation	Greater severity of signs of mild poisoning	Difficulty breathing
Nausea and vomiting	With continued exposure, coma and death	Coma and death

Chapter 5

FIRST AID FOR PESTICIDE POISONING

It is essential that **pesticide** poisoning incidents be recognized immediately, because prompt treatment may mean the difference between life and death.

GENERAL INSTRUCTIONS

1. Stop the **exposure** *immediately* by separating the victim and the pesticide source.
2. If the victim is unconscious, check to see if the victim is breathing. If not, give **artificial respiration**. If highly toxic material is present in the victim's mouth or **respiratory** path, use chest compression, not mouth-to-mouth.
3. **Decontaminate** the victim immediately by washing off any skin **residues** of pesticide, and remove any contaminated clothing. Speed is absolutely essential in this step.
3. Obtain professional help. This should be one or more of the following:
   a. Call 911.
   b. Call the nearest physician.
   c. Call your local or regional poison control center. If you don't know the number or location, call toll-free to 800-222-1222.
   d. Call the Chemical Transportation Emergency Center (CHEMTREC) 800-262-8200.

In all cases due consideration must be given to the protection of yourself and other personnel in the vicinity of the incident. This is critical in the case of a large pesticide spill.

Speed is essential in performing **first aid** for pesticide poisoning. **If you are alone with the victim**, you must give first attention to the victim, especially in re-starting breathing, separating the victim from the pesticide source, and decontaminating the victim's skin. **If another person is with you and the victim**, one of you should perform first aid, the other should seek professional help as described above.

Recognizing the signs and symptoms of pesticide poisoning quickly and following appropriate procedures may help save a person's life, but first aid should never be considered a substitute for professional medical treatment. First aid is only to help the patient get well enough so proper medical treatment may be provided.

After the victim has been fully cared for and professional help has been sought, these additional steps should be taken. As with the first aid procedures, due consideration must be given to your safety and those around you.

1. Bring the **label** and MSDS to provide to the physician or poison control center. You should also save the pesticide container and any remaining pesticide should an official request to see it.

2. Eliminate the source of the contamination to prevent or reduce the risk that others may be exposed to the pesticide. In the case of a significant pesticide spill, this will have to be done by professionals trained to respond to these kinds of emergencies.

3. Decontaminate any clothing or equipment as needed. Never put on clothing previously contaminated with pesticide, and always wash contaminated clothing by itself with detergent and water.

In vector control, we are fortunate that few restricted use and highly toxic pesticides are still in use. Most modern pesticides are easy to mix, load, and apply safely, and have extremely low mammalian toxicity. The most dangerous pesticides used for vector control are **organophosphates** used for mosquito control, **fumigant**s used for rodent control, and some aquatic **herbicides**.

SPECIFIC INSTRUCTIONS

The label and MSDS should be consulted for specific first aid instructions. Below are some of the more common instructions one might expect to see on the label.

Poison in Eyes

Hold eyelids open; wash eyes immediately with a gentle stream of clean running water. Use large amounts of water. **Delay of only a few seconds can greatly increase the extent of injury.** Continue washing for 15 minutes or more. Do not use chemicals or drugs in the wash water. They may increase the extent of injury.

Inhaled Poisons

If victim is in an enclosed space, do not attempt a rescue without proper respiratory equipment. Get the patient to fresh air immediately. Loosen all tight clothing. Apply **artificial respiration** if breathing has stopped or is irregular. Call for emergency help.

Prevent chilling (wrap patient in blanket but don't overheat). Keep patient as quiet as possible.

If patient is convulsing, watch his or her breathing and protect the patient from falling and striking his or her head on the floor or wall. Keep the patient's chin up so air passage will remain free for breathing.

Swallowed Poisons

Call for emergency help immediately. If a non-corrosive substance has been swallowed, label directions, MSDS, or medical personnel from a Poison Control Center may direct you to induce vomiting.

If vomiting is to be induced, place the blunt end of a spoon (not the handle), or your finger, at the back of the patient’s throat; or use an emetic of two tablespoons of salt in a glass of warm water.

When retching and vomiting begin, place patient face down with head lowered, thus preventing vomitus from entering the lungs and causing further damage. Do not let patient lie on back.

Never induce vomiting unless directed by the pesticide label, MSDS, or a medical professional to do so. Do not induce vomiting if:

- Patient is unconscious or experiencing convulsions.
- Patient has swallowed petroleum **products** (kerosene, gasoline, lighter fluid, etc.).
- Patient has swallowed a **corrosive poison** (strong acid or alkaline products).

Chemical Burns of Skin

Remove contaminated clothing. Wash with large quantities of running water. Immediately cover with loosely applied clean cloth (any kind will do). Avoid use of ointments, greases, powders, and other drugs. Treat **shock** by keeping patient flat, warm, and reassured until the arrival of a doctor.

IF YOU ARE THE VICTIM

If you are exposed to a pesticide while you are working alone, remain calm. Symptoms of pesticide poisoning from vector control products are usually mild, and take time to develop.

For possible **ingestion** of pesticides, follow the **labeling** and consult the Poison

Control Center or other medical professionals as quickly as possible.

If you spill a pesticide on yourself, always remove the source of the contamination as quickly as possible – including contaminated clothing, rinse immediately and wash with soap and water as soon as possible. By acting quickly and following label guidelines, you will minimize the effects of the pesticide, and may save your own life. **Call or send for help while you are rinsing and washing!**

If you splash or spill a pesticide in your eyes, wash your eyes with water at once. Use a clear stream of running water, keep your eyes open and wash for at least 15 minutes. After washing your eyes for 15 minutes, get to a doctor. Do not use any medicated eyewash. Call or send for help while you are washing your eyes. In any case, if you swallow a pesticide or get some in your eyes, see a doctor before symptoms develop. Any delay can cause temporary or permanent blindness or other injury; it could even be fatal.

If you have been exposed to a highly toxic pesticide by any exposure route and feel any illness, have someone take you and the label or labeled container to the doctor. Do not delay!

EMERGENCY INFORMATION

If you have employees working with pesticides - you are required to post the name, address, and current telephone number of the physician, clinic, or hospital emergency room that will provide care in the event a person should be poisoned. This information must be clearly posted at all work sites (including vehicles, storage facilities, mixing areas, and loading areas).

It is impossible to overstress the importance of having well-designed emergency poison incident plans in place before an emergency arises. It is especially critical to have contact information available everywhere pesticides are handled. This information must include names, addresses, and telephone numbers for medical facilities for pesticide poisoning treatment, as well as the telephone number for poison control centers. This has been made easier by the adoption of 800-222-1222 as the universal emergency number for all pesticide control centers in California and elsewhere.

Vector control agencies should designate an emergency coordinator. This person must know what to do in case of a poisoning, fire, spill, or other emergency, and should be available 24 hours a day, 7 days a week. The following information should be clearly posted in a prominent place, such as near a telephone in the main district office, or near a telephone in the proximity of the pesticide storage sites:

NATIONWIDE EMERCENCY CONTACT INFORMATION

American Association of Poison Control Centers

703-894-1858

National Pesticide Information Center Hotline

800-222-1222

Chemical Transportation Emergency Center (CHEMTREC)

800-262-8200

Regional Poison Control Centers in California are in Sacramento, Madera, San Diego, and San Francisco
All use emergency telephone number and website address

800-222-1222

http://www.calpoison.org

Chapter 6

PROPER HANDLING OF PESTICIDES

If improperly used, **pesticides** can poison people, pets and livestock. They also can damage beneficial **insects**, birds, fish and other wildlife; harm desirable plants; and they may contaminate soil and groundwater. It is necessary to maintain careful and continuous control over the use and handling of these chemicals during the transport, storage, mixing, loading, application and disposal. Care must be exercised in cleaning equipment, clothing, and persons working with pesticides. Additionally, special precautions are necessary if pesticides are spilled or catch fire.

Certain materials associated with vector control operations, including some pesticides, are considered by **EPA** and DPR to represent hazardous wastes. The identification, handling, transportation, and disposal of hazardous wastes in covered in Chapter 10.

TRANSPORTING PESTICIDES

Pesticides can present a particularly severe **hazard** if they are involved in accidents during transportation. When pesticides are spilled on the roadway, they may catch fire, be scattered by passing cars and trucks, be blown by wind onto nearby crops or people, or be washed into ditches or streams by rain. If they catch fire, the **fume**s and smoke may injure fire fighters, police, and people far removed from the scene of the accident. Even under relatively uneventful circumstances, pesticides may simply contaminate the vehicle, cargo, or people transporting the chemicals. When you transport pesticides, you are legally responsible for them. To reduce the likelihood of pesticide spills or **exposure** of workers riding in vehicles transporting pesticides, the following guidelines should be followed:

1. Pesticides are most safely transported in the beds of trucks.
2. Pesticides should never be transported in the passenger compartment of any vehicle.
3. People should never be allowed to ride in the beds of pick-up trucks carrying pesticides. This applies especially to children as passengers.
4. Pesticides should never be transported in the same compartment with food, feed, or clothing.
5. All pesticide containers in shipment should be secured tightly. This is especially critical for glass containers.
6. Pesticide containers made of paper, cardboard, or similar materials should be protected from moisture during transport.
7. Pesticides in parked service vehicles must be made secure from theft, tampering, and contamination.

STORING PESTICIDES

It is necessary and legally required that pesticides be stored in a safe, secure and well-identified place. Here are some rules which pertain to pesticide storage:

1. Always store pesticides in their original, **labeled** container with the label clearly visible.
2. Always store pesticides in tightly sealed containers and check containers periodically for leakage, corrosion breaks, tears, etc.
3. Always store pesticides where they are protected from freezing or excessive heat.

4. Always be certain that pesticide storage areas are well-ventilated to prevent the accumulation of toxic fumes.

5. Always store different types of pesticides in different areas, to prevent **cross contamination** and the possibility of applying a **product** inadvertently.

6. Never store pesticides in old bottles or food containers where they could be mistaken for food or drink for humans or animals.

7. Never store pesticides near food, feed, or seed.

8. Agencies or programs that store significant amounts of pesticide should have a designated pesticide storage facility.

Requirements for Pesticide Storage:

1. Locking doors
2. Adequate lighting
3. Adequate ventilation
4. Fire extinguishers readily available
5. Spill containment design or equipment
6. Warning placards if Category I or II pesticides are stored – including emergency contact information
7. Personal protective equipment readily available
8. Wash water and eye wash stations available
9. Presence of label and MSDS book for stored materials

Recommended for pesticide storage:

1. Fire resistant construction
2. Emergency shower station
3. Spill containment floor design or drum pallets

MIXING AND LOADING PESTICIDES

All pesticides are potentially harmful, particularly for those who work with them on a daily basis because of the potential for being exposed to large **doses** and the likelihood of chronic exposure. Many pesticide accidents occur when the chemicals are being mixed for use. In California, one of the most dangerous jobs related to pesticide-related illness, is the mixing and loading of concentrated chemicals, specifically low-volume and ultra-low volume **formulations**.

A few common sense rules can make mixing and loading safer, thereby helping you to avoid the leading cause of pesticide-related illnesses:

1. Before handling a pesticide, **READ THE LABEL.**

2. Based on label recommendations, **put on protective clothing** and use other necessary protective equipment. Also from reading the label, follow instructions on what special equipment is necessary. If you have questions concerning protective equipment, contact your county agricultural commissioner or other expert before you open the container.

3. Mix the pesticides outdoors, in a place where there is good light and ventilation. If you must mix or load pesticides indoors or at night, make sure you have good ventilation and lighting.

4. Stand **upwind** of the pesticide to avoid contaminating yourself.

5. Use a sharp knife to open paper bags; do not tear them or the label.

6. Measure accurately; use only the amount you need to apply at the rate specified on the label.

7. When removing the concentrated material from the container, keep the container below your waist if possible to

prevent the possibility of splashing or spilling any pesticide into your face and eyes.

8. If you splash or spill a pesticide while mixing or loading, **stop immediately!** Remove contaminated clothing; and wash thoroughly with detergent and water. Speed is essential if you or your clothing are contaminated. Clean up the spill.

APPLYING PESTICIDES

Careful attention to a few simple guidelines during pesticide application will greatly increase your chances of effectively controlling the pest. At the same time, attention to these details will make the job much safer for you, other people, pets, livestock, and the surrounding environment.

1. Before you begin the application, **READ THE LABEL**. Don't trust your memory for details concerning the use of any pesticide.
2. Check the application equipment. Look for leaking hoses or connections, plugged or worn **nozzles**, and examine the seals on the filter openings to make sure they will prevent **spillage** of the chemicals.
3. Calibrate your equipment before use. Make certain that your equipment is adjusted according to the manufacturer's specifications and meets label requirements for the product being applied. This will assure that the proper dosage is being applied to the target site.
4. Before the pesticide application starts, clear all livestock, pets and people from the area to be treated. Although it would be the ideal situation, most ULV labels do not require this. Always check the label for any specific restrictions.
5. Apply the pesticide at the recommended rate. Do not exceed the maximum application rate specified on the label or the written recommendation.
6. Apply pesticides only at the correct time and under acceptable weather conditions – check the label for specific limitations. Avoid applying pesticides when temperatures are extremely high or low. Be especially careful when temperatures exceed 85°F or are below 50°F.
7. When handling category I and II toxic pesticides, one should try to not work alone.
8. Use extreme care to prevent the pesticide from contaminating unintended target sites (e.g., streams, ponds, lakes or other bodies of water). Remember also that direct application of pesticides to these types of bodies of water requires special permitting.
9. Avoid situations where the pesticide may **drift** from the application area and contaminate **non-targets**.
10. Do not contaminate food or feed through careless application methods.

EQUIPMENT CLEAN-UP

After completing the application of any pesticide, immediately clean the mixing, loading, and application equipment. The cleaning operation can be somewhat hazardous if proper precautions are not followed. People who clean the equipment must:

1. Know the correct procedures for cleaning and decontamination.

2. Wear the appropriate personal protective equipment.

3. Know and use the specific area set aside for cleaning. This will usually be on a wash rack or concrete apron that has a well-designed sump to contain all contaminated wash water and pesticides for later disposal, or in the field where rinse

water may be considered part of the application.

DISPOSAL METHODS FOR PESTICIDE WASTES

GENERAL CONSIDERATIONS

Waste materials should be considered hazardous to the public, the people handling them and the environment. Deciding how to dispose of pesticide wastes should be done on a case-by-case basis. Materials that meet the legal requirements as hazardous wastes in California (some pesticides, used crankcase oil, used antifreeze, etc.) must be disposed of according to special rules controlled by the California Department of Toxic Substances Control (DTSC). This is covered in Chapter 10. Waste materials that are not classified as hazardous waste can be disposed of in other ways, but should never be dumped into drains or water courses of any kind. The best way to avoid all waste pesticides is to use them up in legal pesticide applications. Even the rinse water used in cleaning pesticide equipment can be used as a **diluent** in tank mixes that contain water **soluble** pesticides.

PESTICIDE CONTAINER DISPOSAL

Always dispose of pesticide containers in a manner specified on the label. Pesticide container disposal can be a significant problem, particularly if you have a large number of containers. Many pesticide containers can be recycled, either as a part of a regular recycling program, if approved on the label, or by returning to the chemical supplier. Many chemical companies now re-cycle their pesticide containers.

Refer to Chapter 10 for instructions on disposal of empty pesticide or other containers that originally held hazardous wastes.

Before disposing of any empty pesticide container, it must be rinsed. The correct rinse procedure follows:

1. Empty the container into the mixing tank and allow the pesticide to drain for an extra 30 seconds. (Do not fill the tank to the desired level yet. First complete the triple rinse method described here, adding the rinse solution to the tank as described in (4) below.
2. Add the correct amount of water for thorough rinsing as follows:

Size of Container	Amount of Rinse Water
Less than 5 gallons	One-fourth container volume
5 gallons or more	One-fifth container volume

3. Replace the container closure; then rotate and shake the container, so that the rinse reaches all interior surfaces.
4. Drain the rinse solution from the container into the mixing tank. Allow the container to drain for an extra 30 seconds after emptying.
5. Repeat this rinsing procedure at least two more times for a total of three rinses. **Remember**—it is important to empty each rinse into the mixing tank so that the pesticide goes on the target for which it is intended (this procedure also saves money). Never pour pesticides down an ordinary drain or flush them down a toilet!
6. Now the triple rinse procedure is complete. Let the container dry and replace the cover.

Many containers will be discarded after one use. California regulations concerning pesticide container disposal do not apply to containers in which household pesticides have been packaged. However, these containers (except **aerosol** cans) should be rinsed carefully and destroyed to prevent their reuse.

DISPOSAL OF UNUSED AND EXCESS PESTICIDES

Disposing of unused (still in the **original container**) and excess (already mixed, but not needed) pesticides can be a significant problem. For vector control agencies, the easiest solution is to mix only as much product as will be needed. This is critical for *Bacillus thuringiensis var. israelensis* (*Bti*) because it looses efficacy after 24 hours.

The best way to dispose of any currently labeled pesticide is to apply it according to the label. If that is not possible because of a label change, contact your local County Agricultural Commissioner – in many instances, you will be directed to use the remainder of the product per label instructions. For any currently labeled pesticide, the best alternative would be to find another person or area with the same pest problem, so that the pesticide gets used up legally and effectively.

If you cannot find another area with the same problem, you might decide to dispose of the pesticide in an approved location. Contact the California Department of Pesticide Regulation, or your County Agricultural Commissioner for specific information on regulations and pesticide dump sites.

PERSONAL CLEAN-UP

After you have completed the pesticide application, disposed of excess material, and cleaned the application equipment, you should thoroughly wash all your protective equipment. Remove your work clothes and place them in an area separate from other laundry items or properly dispose of them if they are disposable coverall, e.g., Tyvek®. Do not allow children to play in or with the contaminated clothing. The pesticides on your work clothes could contaminate people who touch them, so warn whoever will be washing the clothes of the possible danger, and tell this person that pesticide-contaminated clothing should be washed separately from other clothing. Now take a shower. Wash yourself completely with soap and water. Remember to include your hair and fingernails in the wash-up. Do not put on *any* article of clothing worn while working with pesticides until after it has been laundered.

PESTICIDE SPILLS

Reporting of pesticide spills is required under Section 105215 of the Health and Safety Code (Appendix 2). Also, since some pesticides qualify as hazardous materials, a variety of local, county, and state agencies will become involved in reporting and cleanup, especially if the spill occurs while pesticides are in transit. In this case, peace officers are often the first responders, and they are required to report pesticide spills under the California Vehicle Code. Pesticide spills that cannot easily be cleaned-up and **decontaminated** by vector control program personnel can be reported directly to the local health officer who will in turn contact the County Agricultural Commissioner or the County Health and/or Environmental Health Department. One should also use common sense judgment to determine the danger that is created with a spill, e.g., a spill that occurs in a confined and enclosed area versus an open area.

In spite of the most careful use and handling of pesticides, accidental spills and fires occasionally occur. These range in size from small spills of a household pesticide container to huge fires involving entire manufacturing warehouses filled with the most toxic pesticides. Intelligent planning, knowledge of the chemicals involved and calm consideration of the actual **hazard**s to be dealt with during the emergency will reduce the risk and damage resulting from the accident. Pesticide spills can and do happen anywhere pesticides are transported, stored, or applied. When a spill occurs, it should be cleaned up as quickly and safely as possible. For some pesticides and **formulations**, such as Altosid® pellets, clean-up is as simple as collecting the spilled product and using it. A few general rules apply to all pesticide spill clean-ups.

1. Avoid exposure of people and animals to the pesticide. If you spill a pesticide, immediately see to it that no one is exposed or contaminated by accidentally walking into the spill or breathing the **fume**s.
2. Start by putting on protective clothing so that you do not contaminate yourself.
3. Provide some sort of a barrier to the spread of a liquid pesticide. A barrier may be made of dirt, sawdust, old newspapers or anything that will soak up the pesticide.
4. Remove the contaminated materials to a safe place. If the spill is inside the home or another building, soak up liquid pesticides or sweep up powders and remove them to the outside. Ventilate the area to prevent the **buildup** of toxic fumes.
5. Thoroughly clean the affected surface. Consult the label for specific disposal and decontamination instructions. Take care to prevent the wash from spreading and possibly contaminating a larger area. Make sure any wash does not go into storm drains or sewer systems.
6. If the spill that cannot be easily cleaned involves a public area, such as a highway, notify the police, sheriff's office, fire department, the highway patrol, or other local emergency services agency.
7. While waiting for emergency personnel to arrive, do what you can to prevent others from being exposed to the pesticide.

Remember: The highest priorities are to prevent exposure to the pesticide and to prevent the spread of the spill. In the event of a large spill that cannot be easily contained, contact emergency services personnel, tell them about the nature of the chemical and explain to them what you know about the pesticide involved. If it is a Toxicity Category I or II pesticide, their lives may depend on your warning!

PESTICIDE FIRES

Small Fires

If a fire occurs in an area where pesticides are used or stored, and the fire is very small and easily extinguished, you may elect to attack it yourself if you follow certain precautions:

1. Use foam or carbon dioxide from a fire extinguisher in lieu of water if at all possible.
2. Wear protective safety equipment.
3. Avoid exposure of smoke, mist, spray, **runoff**, and concentrated pesticide chemicals.

Large Fires

In the event of any large fire, contact emergency fire services immediately! When large fires involving the presence of very toxic materials (including pesticides) occurs, the fire department responding to the emergency call will seek the aid of specialized agencies which deal with such chemical emergencies.

Whenever pesticides are involved in fires, they can create special hazards. Anyone in the vicinity of the fire may be exposed to toxic fumes, poisonous runoff, and concentrated pesticides from leaking or exploding storage containers. Here are some general rules that apply to pesticide fires.

Maintaining communications with the responding fire department is essential. Keep them updated on what chemicals you are storing, where it is stored, how much is being stored, and supply them with any information such as material safety data sheets they may request concerning the nature of the chemicals. This may allow them to prepare for possible emergencies and may save lives and property.

Before the fire department arrives you should:

1. Not risk your own health to fight a large fire — consider the risks of potentially toxic smoke, explosion, and your limited capacity to control the fire. You may inadvertently risk the health and safety of the professionals or others, particularly if you are injured in your attempts. Do not attempt to fight the fire unless you have been trained to do so; it is the job of highly trained professionals to fight fires.
2. Avoid poisoning: Keep yourself and others out of smoke, mist, spray, and pesticide runoff.
3. Notify all those in close proximity of the fire and downwind and tell them to evacuate the area.
4. Wear personal protective equipment if it can be safely retrieved.

After the arrival of the fire department, you should:

1. Without risking your health or safety, take steps to minimize contamination of areas outside the fire zone by runoff from fire fighting. This can help contain spilled pesticide and thus avoid affecting people and domestic animals and the environment. It is especially important to avoid runoff of contaminated water into nearby streams or lakes.
2. Cool nearby pesticide containers; move vehicles and any threatened mobile equipment if it is safe to do so.

ADVERSE PESTICIDE RELATED EVENTS

For vector control agencies, adverse pesticide related events must be reported to the California Department of Public Health and the County Agricultural Commissioner.

Adverse events (conspicuous or suspected) that must be reported:

1. Any human illness associated with a vector control pesticide application.
2. Any report of harmful non-target effects of an application to plants, domestic animals, or wildlife.
3. Any pesticide spill requiring an emergency services response.

Chapter 7

PROTECTIVE CLOTHING AND OTHER SAFETY DEVICES

The **hazards** associated with contamination by any pesticide vary with the type of pesticide and the route of exposure. For vector control technicians, mixing and loading of pesticides has become much less hazardous overall with the gradual shift away from restricted-use pesticides. However, vector control technicians still work with highly concentrated **herbicides** and some **insecticides** that can pose occupational hazards.

By wearing protective clothing and using available safety devices such as face masks, goggles, and gloves, the danger from contamination by pesticides can be minimized. This is especially important to workers who may be allergic to certain **products**, or when working with pesticides in a manner that might lead to skin irritation or accidental splashing into eyes.

Information about required safety devices and clothing is available on pesticide **labels** and on material safety data sheets. Personal and environmental safety devices should be available at all work sites where pesticides are handled, mixed, or used. If such devices are not present, workers should immediately stop working with pesticides and report the need for required safety equipment to a supervisor.

The use of pesticide safety clothing and other safety devices helps protect people from pesticide **exposure** and contamination. However, they are never a proper substitute for taking common sense precautions when using pesticides.

MINIMUM PROTECTIVE CLOTHING

Whenever you handle pesticides it is important to protect yourself from exposure to the chemical, including your head. You should always wear a clean cap or hat, clean coveralls, or long-sleeved shirts and trousers. The wearing of shorts, sandals, tank tops and other articles of clothing that result in large areas of exposed skin should never be permitted in a pesticide work place, even during hot weather.

Anytime you are working around pesticides, including cleaning equipment and vehicles, or cleaning up any spill or decontaminating an area, proper personal protective equipment must be worn and appropriate handling procedures must be followed. The extent of protective equipment required is determined by the degree of hazard of the pesticide. Some general guidelines for interpreting pesticide label statements which require protective clothing and equipment are available from the California Department of Food and Agriculture (FAC Section 12980-12988) (http://www.leginfo.ca.gov/cgi-bin/calawquery?codesection=fac&codebody).

TYPES OF PROTECTIVE CLOTHING

Skin contamination is the leading cause of occupational pesticide-related illness. Therefore, protecting the skin should be given first priority. Coveralls, aprons, spray suits, gloves, hats, boots, goggles and face shields are designed to protect pesticide users from getting the pesticide on the skin or into the eyes.

Coveralls

There are two types of coveralls: light weight disposable coveralls made of chemical-proof material, and washable cloth coveralls. Disposable coveralls are lightweight and reasonably comfortable in hot weather and offer excellent protection if not damaged. Some disposable coveralls come with directions for re-use after laundering. Coveralls that become severely contaminated should be discarded. The second type of coverall is made of washable fabric and may be re-used many times. It is critical that if washable cloth coveralls are worn, they must be laundered before each day's work. Cloth coveralls are adequate for working with dry pesticides (granular **formulations** or **bait** blocks), and some liquid pesticides used in vector control, however, if the coveralls become wet or even damp with pesticide, they will act as a continuous source of contamination. In the event a liquid pesticide is spilled onto cloth coveralls, the coveralls must be removed. It the pesticide has significant dermal toxicity, the person wearing the coveralls should shower and put on clean clothing immediately.

Aprons

When pouring or otherwise handling category I or II liquid pesticides, you should wear additional protection in the form of a rubber apron or chemical-proof disposable (Tyvek®) coveralls. Be certain the apron will resist the solvents used in formulating the pesticide. Check the label for any specific requirements. It should cover your body from your chest to your boots.

Spray Suits

Labels for Category I or II pesticides may require wearing of spray suits during handling, mixing, and application. These suits are made of liquid-proof and tear-**resistant** materials. Their use in hot weather tends to be very uncomfortable; and such conditions can become an occupational hazard aside from pesticide exposure concerns. Consequently, workers should avoid doing work with such pesticides except when weather is

CHECKLISTS FOR AVOIDING PESTICIDE EXPOSURE

For Avoiding Dermal Exposure

- Check the label for special instructions or warnings regarding **dermal exposure**.
- Use recommended protective clothing and other equipment as listed on the label.

For Avoiding Oral Exposure

- Check the label for special instructions or warnings regarding **oral** exposure.
- Never eat, drink, or smoke while working with any **pesticide**.
- Wash thoroughly with soap and water before eating, drinking or smoking.
- Do not touch your lips to contaminated objects (such as **nozzles**).
- Do not wipe your mouth with contaminated hands or clothing.
- Do not expose food, beverages, drinking vessels, or cigarettes to pesticides.
- Wear a **face shield** when handling concentrated pesticides.

For Avoiding Respiratory Exposure

- Read the label to find out if **respiratory** protection is required.
- If respiratory protection is required, use only an approved respiratory device.
- Avoid working for extended periods in areas where volatile pesticides are used or stored.

For Avoiding Eye Exposure

- Read the label to find out if eye protection is required.
- If eye protection is required, use goggles to protect your eyes or a face shield to protect your eyes.
- Pour or mix pesticides below eye level.

cool. Fortunately, very few Category I or II pesticides are used in most vector control operations.

Gloves

The skin on your hands can absorb pesticides and their solvents. When working with liquid pesticides, protect your hands by wearing liquid-proof gloves. Gloves of natural rubber will provide protection from OPs and **carbamates.** Unlined flexible plastic gloves are considered best for all other pesticides. Be sure that they are designed for use with solvents and pesticides.

Leather gloves may provide satisfactory protection when working with dry pesticides that have no dermal toxicity. However, in almost all other situations their use should be avoided. As a general rule, gloves should be made entirely of material that will not absorb liquid (and pesticides). Cloth, leather, or other materials may become contaminated leading to constant (chronic) exposure. When using your gloves, wear your sleeves so that they prevent spills and splashes from running into your glove and onto your hand.

It is essential that gloves worn to protect workers from pesticide contamination be in good repair. Gloves with rips, tears, or other defects will provide a false sense of security, and probably will be worse than not wearing gloves at all.

Hats

Small amounts of pesticide may cause skin irritation or other illness if exposure continues for several days. Pesticide workers applying liquid products that may have **dermal toxicity** should use a liquid-proof hat preferably made of washable plastic. The hat may be hard or it may be flexible elastic. In either case it should have a plastic sweatband and be washed thoroughly after each use. Cloth, straw, or felt hats are not recommended.

Boots

Most vector control operations require wearing some type of boots. Field personnel applying pesticides for mosquito control often wear rubber boots because they are walking through water. Other vector control personnel applying **rodenticides** or ant baits are at greater risk from venomous **organisms** and thorns than they are from pesticides and probably should wear good quality leather boots.

There are times when it is necessary for vector control workers to wear rubber boots to protect them from pesticide exposure. Rubber boots are particularly important when mixing or loading Category I or II pesticides. The most effective type of boot for protection from toxic materials is knee-length pull-on boots without buckles, laces, or other closing devices. Such boots provide maximum protection from toxic liquids and are easily cleaned. These types of boots should be worn with trouser legs outside, not inside the boots. In this way, you will avoid spills and splashes running into the boot and onto your leg. Wash boots thoroughly, inside and out, after each use.

CARE OF CLOTHING

Wear clean clothing daily. If your clothes become contaminated with pesticide, shower and change them immediately. If your clothing becomes highly contaminated, do not attempt to clean them – dispose of them in a safe manner. Do not store contaminated clothing. Wash any pesticide-contaminated clothing separately from family laundry. If you are manager of a program, make sure personnel are provided appropriate protective clothing as required by state and federal regulations.

TYPES OF EYE, MOUTH, AND FACE PROTECTION

The mouth and eyes are high risk areas for pesticide exposure, and appropriate personal protective equipment is essential when mixing, loading, or applying many Category I and II pesticides.

Goggles

It is especially important to protect the eyes with chemical goggles when handling **dusts**, **wettable powders**, or granules. Goggles are manufactured so that they fit over ordinary eyeglasses. Goggles with prescription eye pieces can also be obtained for workers who must wear this kind of protection frequently. Goggles must be washed with soap and water after each use. Check the label for specific eye protection requirements or recommendations.

Face Shields

A face shield for full face protection may be advisable or required by the label for some herbicides used for vector control – particularly when loading or mixing liquid concentrates. Effective face shields are made of clear plastic, attach to a hard hat, and can be raised or lowered as needed. Face shields must be washed with soap and water after each use.

PROTECTION FROM INHALATION HAZARDS

> You **must** wear a respirator if the pesticide label requires one. You **may** need to wear a respirator if the pesticide label says, "Avoid breathing vapor or mist." Your supervisor must give you a respirator when it is needed. You **must** wear it. — *Pesticide Safety Information, HS-1746, California Department of Pesticide Regulation*

Some pesticides can represent significant hazards of exposure through **inhalation** or respiration. Some materials can cause damage to the nose, mouth, throat, or lungs. These hazards can be eliminated almost completely by use of various devices designed to protect workers against these kinds of agents. Any device worn to protect a worker from pesticide inhalation hazards must have federal approval for use with pesticides.

Devices designed to protect the respiratory (breathing) system are called respirators, and must be worn when working with pesticides that may be harmful when inhaled. There are different types of respirators that are designed to protect you from different kinds of inhalation hazards. Full-face respirators are designed to protect you from pesticides that can irritate your eyes and lungs.

Some respirators operate under positive pressure, i.e., the devices have a pump system to force purified air into the mask. Negative pressure respirators require at tight seal of the mask around the nose and mouth, and filter air as it is sucked through some filtering media contained in a **cartridge** or **canister**. The filtering material in the cartridges and canisters are designed to protect against vapors of specific chemicals.

Any respirator must fit your face. Respirators come in different sizes, and it is essential that workers know how to test for proper fit. This testing should take place in an area where there is no chance of pesticide exposure. Also any respirator to be used to protect workers from pesticide vapors must be labeled as approved by the National Institute for Occupational Safety and Health (NIOSH).

Some people cannot use respirators. High blood pressure, heart disease, lung disease, and a perforated eardrum are among the problems that may interfere with effective use of a respirator. A physician can certify if certain workers should not use a respirator and thus should not work around pesticide vapors. Medical clearance is required prior to using most if not all respirators.

Beards, bushy mustaches, or long sideburns may interfere with proper fitting of respirators. In these cases there are special respirators that can still provide a tight seal.

SCBA Protection

Some **fumigant** labels require you to wear a self-contained breathing apparatus (SCBA). With this type of device all air for breathing is contained in a tank of some kind, and no outside air enters the respiratory system. This type of protection will rarely, if ever, be required with public health pesticides.

Chemical Cartridge Respirators

Most respirators of this type consist of half-face masks, with respirators that cover the nose and mouth, but do not protect the eyes. These mask should be fit tested prior to use. They have one or two cartridges that screw into the face piece and can be easily removed for replacement. These types are usually equipped with one-way valves that allow the inhaled air to pass through the cartridges. There is a separate exhalation valve. These respirators are designed for use where high concentrations of pesticides are unlikely. They are used, for example, when mixing or loading pesticides outdoors with adequate ventilation.

Respirator cartridges usually contain an absorbing material such as activated charcoal. They also have filter pads to remove dust and spray particles, thus prolonging the life of the absorbent material. The life of chemical absorbing cartridges or canisters varies according to the concentrations of pesticides encountered. Their effective life is also affected by humidity, temperature, and the volume of breathing. Tests show that these devices gradually lose their effectiveness during storage because of the exchange of air within the unit due to changes in temperature and atmospheric pressure.

Filter cartridges should be replaced when:

- Directions on the pesticide label say so.
- The respirator maker says so.
- You first smell or taste a pesticide, or experience irritation.
- At the end of each day’s use.

Follow the rule that replaces the filter cartridge according to the manufacturer.

Positive Pressure Respirators

Powered air pressure respirators (PAPRs) are designed to supply full-face protection. They cover the eyes as well as the nose and mouth. A proper fit is absolutely essential with this type of respirator. PAPR's incorporate a battery powered air pump worn on the belt, feeding filtered air into the head piece in a constant flow. These respirators are often used by individuals involved in vector-borne disease surveillance operations, such as plague or hantavirus investigations.

USE AND CLEANING OF PERSONAL RESPIRATORY DEVICES

The following use and cleaning practices are necessary to maintain the equipment's effectiveness in protecting your health.

- All negative pressure respirators must be fit- tested to ensure the mask is properly sealed. A proper fit can be obtained by adjusting headbands, or switching to another size or respirator type.
- Change respirator filter cartridges as indicated above.
- Clean respirators after each use. Remove and discard used filter pads, and cartridges as needed and wash face

pieces with soap and warm water. Rinse thoroughly in clean water to remove all traces of soap. Dry the face piece with a clean cloth that is not contaminated with pesticides or place the face piece in a well-ventilated shady area (sunlight will eventually ruin the rubber parts). Replace the used cartridges, and filter pads with fresh ones.

- Store the respirator and its freshly replaced parts in a dark, clean, and dry place—preferably in a tightly closed paper or plastic bag.

When respirators are broken or otherwise inoperable, they must either be fixed prior to use, or your supervisor must supply new ones.

REMEMBER: Respirators only protect pesticide workers from breathing chemicals. When pesticides are used, protection of the skin is also important.

Chapter 8

EQUIPMENT AND CALIBRATION

Many over-the-counter **pesticides** for household and garden use are sold in a form ready for application. Solid **products** are often spread simply by sprinkling from the boxes in which they are furnished, and some liquid products can be sprayed from simple, small pressurized equipment. Several pesticides used for vector control are available in granular forms that can be applied by hand or through commonly available equipment like fertilizer **spreaders** or horn seeders. Other pesticides used in vector control require specialized equipment for their application. Some public health pesticides come in concentrated form and must be **dilute**d to produce what is known as a **tank mix**. Mosquito adulticides that are applied as fogs or by using ultra-low volume techniques require equipment designed for these purposes. Because the **labels** of the pesticides used in these kinds of applications carry specific restrictions on droplet size and application rates, it is critical that the equipment be maintained in good working order, and that the equipment is calibrated frequently to make sure the applications conform to label requirements.

The first question that needs to be asked when choosing the type of pesticide application equipment to be used in vector control operations is whether a liquid or a solid (**dust** or pellets) pesticide formulation will be used. For liquid **formulations**, the basic choice will hinge on the spray techniques to be used. Spray techniques, in turn, often are classified on the basis of the spray volume used in an application. The three basic types of liquid spray techniques are high volume (40 gallons per acre or more), low volume (0.5–40) gallons per acre), and ultra-low volume (0.5 gallons per acre or less).

PESTICIDE APPLICATION EQUIPMENT

The type of application device to be used for a specific job should be selected after careful consideration of the location and size of the area to be treated and the pest to be controlled. There are two basic types of equipment used to apply public health pesticides: powered and unpowered.

UNPOWERED EQUIPMENT

Generally, unpowered equipment is suitable for relatively small pesticide applications, such as **spot treatments** of aquatic sites where mosquito **larvae** are present. Typical unpowered equipment for liquid pesticides includes the some backpack and tank sprayers. Sometimes these types of equipment are called compression sprayers. Unpowered backpack sprayers are really just tank sprayers with straps to permit them to be carried like a backpack. These sprayers sometimes have a continuously operated pump lever to maintain pressure in the pesticide tank. Others are pumped up by hand until pressure reaches a certain point. The pesticide then can be sprayed until the pressure drops below the level where the sprayer works effectively. Then it must be re-pressurized. Pressurized tank sprayers and backpack sprayers come in sizes ranging from about 1–5 gallons. Sprayers that are not backpack types are often referred to as “hand can, or by their capacity, such as a “3-gallon sprayer.”

Pesticides in solid form (granules, slow release briquettes, powders, etc.) can be applied by hand, with small crank-operated spreaders, dust cans, or similar devices. **Aerosol** bombs are also unpowered pesticide **applicators.**

Small unpowered equipment is inexpensive, simple to use, and easy to clean and store. Small areas (less than an acre) can be treated by a single person in a relatively short period of time. However, **calibration** of small unpowered devices can be difficult, and larger-capacity liquid tank sprayers may be difficult for physically smaller technicians to handle.

POWERED EQUIPMENT

For large-scale pesticide applications, powered equipment is essential. This type of equipment ordinarily is mounted permanently in terrestrial or aquatic vehicles, or is attached to fixed- or rotary-wing aircraft. On the other hand, not all powered equipment is large. Some backpack sprayers may use small 2-cycle engines as a power source, and some of these miniature units have been used for ULV applications.

All power equipment works by pumping or blowing product from a storage tank through a distribution line or hose to various types of control mechanisms. The control mechanisms may be mounted on various devices such as guns, **booms**, or cylinders that can be aimed. For liquid products, the pesticide is applied through **nozzles** which control the shape of the spray pattern, the rate of flow of the spray, and the size of individual spray droplets. Nozzles are available in many sizes and configurations. Solid pesticides are spread using hoppers or air streams to propel the particles.

The details of the equipment are matched to the needs of the job and vary from machines designed to shoot pellets long distances to ULV machines designed to create tiny droplets to **drift** on the wind.

TYPES OF POWER APPLICATORS

There is a variety of powered application equipment used in vector control, including tank sprayers, **mist blowers**, granular applicators, and ULV sprayers. Vehicles used with power applicators have become highly specialized, and are often equipped with complex computerized tracking devices that produce maps of areas treated and records of vehicle speed, wind velocity, temperature, and pesticide application rates.

FOGGERS AND AEROSOL GENERATORS

These types of devices work by breaking pesticide formulations into very small droplets. The output is may be visible as a cloud or a fog. The pesticide cloud is produced in one of two ways. In **thermal fogging**, the fog is produced by some type of heating element called a thermal generator. Here the pesticide is carried on heated oil particles. In **cold fogging** droplets are produced by atomizing nozzles, spinning disks, or high pressure. This form of fogging is much less visible. Large truck-mounted **foggers** have been used almost exclusively for control of flying **insects** such as mosquitoes and gnats. Small portable foggers have been used for control of roaches and stored product insects in warehouses and similar structures.

Fig. 8.1 A thermal fogger (Curtis Dyna-Fog, Ltd.)

LOW PRESSURE TANK AND BOOM SPRAYERS

Low pressure sprayers deliver a low volume (0.5–40 gallons per acre) of dilute spray through nozzles with 30-60 pounds per square inch (**psi**) pressure. Tank and boom sprayers are designed to apply either undiluted (neat) or mixed product from a supply tank, through a single hose or a series of hoses through one or more nozzles. For vector control, this type of sprayer is usually mounted to an all terrain vehicle (ATV), an amphibious vehicle, or a low-speed aircraft to treat pastures. The purpose of the booms is to achieve wider and more even coverage for each pass of the vehicle carrying the sprayer.

This type sprayer comes in a variety of sizes, from small units with 10 or 15 gallon tanks mounted on ATVs to large units with water capacities of 1,000 gallons or more mounted on large flatbed trucks with a series of nozzles designed for roadside weed spraying.

Although boom sprayers are used in vector control, specific distribution is more important than uniform application of **larvicides**, so single-nozzle hand-gun type sprayers are used more frequently than boom sprayers.

Larval mosquito control products such as the liquid formulations of microbial **insecticides**, *Bti* and *Bs*, Golden Bear oil (GB-1111) and some **herbicides** are most commonly applied using this type equipment. For most of these products, adequate agitation is not a significant problem. For **wettable powder** formulations a mechanical **agitator** may be required.

Low pressure boom sprayers are relatively inexpensive. They are light in weight, have enough capacity to cover large areas, and may be adapted to many uses. However, low pressure boom sprayers are not useful when high volume is required because their rate of application is low. They cannot penetrate dense **foliage** because they operate at low pressure. They produce visible fogs, which some people find objectionable.

HIGH PRESSURE SPRAYERS

Rarely used in vector control operations, **high pressure sprayers** are often called "**hydraulic sprayers**". This type sprayer is designed to apply large volumes (40 gallons per acre or more) of liquid at high pressure.

High pressure sprayers are more versatile than low pressure units. They can deliver very large volumes at pressures high enough to penetrate dense foliage or reach the tops of tall trees. They are usually well built, often have **mechanical agitation**, and are designed to resist wear. High pressure sprayers are also expensive. They are heavy and they require large amounts of water and fuel. Because the spray is produced at high pressures, there is a tendency for it to form small droplets subject to drift.

AIR BLAST SPRAYERS

This type sprayer is rarely used for vector control, but may occasionally used for fly control. These units use a high speed, fan-driven air stream to disperse the spray. A series of nozzles **inject** the spray into the air stream which breaks up the droplets and blows them onto the target. They can deliver either high or low volumes of spray.

The **air blast** sprayers give good coverage and penetration. They use low pump pressures and have mechanical agitation. They can be operated at low volumes and therefore require small amounts of water. The disadvantages of air blast sprayers are that they may produce small droplets that may create a drift hazard. Because of this they must be used under calm weather conditions. Typically these are relatively large, heavy machines that are not appropriate for use in small areas.

LOW VOLUME AIR SPRAYERS (MIST BLOWERS)

Mist blowers are a type of **low volume sprayer** used to control both larval and adult populations of mosquitoes. Mist blowers are characterized by relatively low fluid pressures, with flow rates of several ounces per minute. Dispersal of liquid insecticides is done using high air velocity. Typically, the product is run through hoses to a metering device which may or may not be connected to a conventional nozzle. Some large mist blowers are mounted on trucks and dispense mists of pesticide though nozzles mounted within large open cylinders. The cylinders can be aimed, sometimes by remote control, thus permitting aiming of the spray.

Fig. 8.2 A high pressure mist and dust sprayer (Buffalo Turbine Corporation)

Backpack-sized units can be used to treat areas up to several acres quickly and efficiently. The main advantage over air-blast sprayers is the lower volume of water needed.

Mist blowers are particularly useful in mosquito control for treating dairy lagoons, roadside sources, and for applying a residual adult control product to individual properties.

Small units are highly portable. Larger units can be mounted on pickup trucks or small trailers. A large mist blower can be used to treat many acres in a single day.

Backpack-type power mist blowers allow rapid treatment of up to several acres by individual vector control technicians.

Although this type of unit is best suited for liquid applications, some manufacturers offer the option of equipping them with hoppers for us with dusts and pellets or granules. Large units are unusable in areas without roads. Many large units also require two people for operation – one to operate the sprayer while the other drives the vehicle.

ULTRA LOW VOLUME SPRAYERS (ULV)

Ultra Low Volume (ULV) sprayers (i.e., cold fogging) are designed to apply extremely low volumes of highly concentrated pesticides in the form of very small (5-30 micron) droplets into the air. A micron, abbreviated “µm”, is equal to 1/25,000 of an inch. ULV sprayers are used primarily against adult mosquitoes, and require the use of insecticides formulated for this purpose. These formulations are either sprayed as ready to use without additional dilution or diluted with light **oils**. Most ULV sprayers utilize a small electric pump that can be very finely adjusted to vary droplet size and flow rate. Many commercial ULV formulations are available for adult mosquito control. A typical formulation contains a small concentration of **pyrethrin** (5-10%) combined with a synergist such as PBO. The remainder of the pesticide usually consists of an oil of some kind. With the exception of malathion, ULV products have a low percentage of **active ingredient**. ULV sprayers may be mounted in trucks, amphibious vehicles, or in aircraft. They are currently the most widely used type of sprayer for adult mosquito control.

Fig. 8.3. A ULV pesticide sprayer (Curtis Dyna-Fog, Ltd.)

ULV spraying is a highly effective means of adult mosquito control and a sensible alternative to the old fashioned **thermal** fogging machines. The combination of extremely low volumes (often less than one ounce of total liquid volume per acre) and pesticides having very low toxicity for humans and other vertebrates makes them very safe for both humans and other **non-target organisms**.

Effective ULV spraying requires careful attention to weather conditions. The very small droplets of concentrated pesticide tend to drift out of the target zone at high wind speeds, and generally, the higher the wind speed during application, the lower the effective **swath**. ULV applications are generally not effective for mosquito control at wind speeds over 10 MPH. Temperature is another important consideration because of the effect it can have on evaporation of the pesticide. The pesticide label should be consulted for specific meteorological limitations

Temperature inversions occur when temperatures at ground level are lower than temperatures at higher altitudes. This is the reverse of the normal temperature situation near the surface of the earth. During inversions, cold air is trapped by the warm air above it, and there is little vertical mixing of air. Under these conditions, the very small droplets produced by ULV sprayers remain suspended in the cool air within several feet of ground level. For some agricultural applications, and for application of herbicides, spraying under these conditions is considered undesirable because the spray droplets may remain suspended in the cooler air at ground level and damage non-target organisms. However, a temperature inversion is considered desirable for ULV mosquito control applications, because at the time of spraying female mosquitoes are **host** seeking (seeking a blood meal) near ground level, and the risk of damage to non-target organisms is low. If there is no lateral air movement, and no temperature inversion, the very small droplets will rise with vertical air currents above the level where they will effectively kill ground-level mosquitoes.

Because of the effect of weather variation on ULV applications, calibration should be checked frequently for flow rate and droplet size. Many new labels if not all require an annual calibration certification.

SOLID PESTICIDE APPLICATORS

Dusters

Equipment for dispersing dusts can be obtained in a variety of configurations, both powered and unpowered. Some equipment used for application of liquid pesticides can be used for solid materials with the installation of accessory hoppers and other devices.

Fig. 8.4 A Maruyama powered backpack sprayer for misting or dusting (Clarke Mosquito Control)

Granular Pesticide Spreaders

These devices are designed to apply coarse, dry uniform size particles to soil or water. The two major types are granular blowers (backpack or truck mounted) and seed or fertilizer **spreaders** mounted on some piece of equipment.

Granular spreaders eliminate the necessity of mixing the formulation with a solvent. The equipment is relatively inexpensive, and there is little drift **hazard**. The granules themselves are less hazardous to the applicator. Existing equipment (such as seeders) can often be modified to spread granules.

Power granular applicators allow vector control technicians to treat habitats where liquid products may not be effective, and allow a single technician to treat many acres in a day. Power backpack granular blowers are particularly effective in treating areas that are difficult to reach.

It may be difficult to calibrate power granular applicators because of the difficulty in maintaining constant travel speed while walking or driving. For units mounted on terrestrial vehicles or on backpacks, the equipment must be re-calibrated for each different product or formulation.

SPRAYER COMPONENTS

TANKS

Most sprayers have a single tank that holds mixed pesticide ready to be applied. For some larger truck-mounted sprayers, there are separate tanks for product and clean water, with a much smaller mixed (injection) tank of mixed product.

Some tanks may contain an agitation device, especially those designed to work with insoluble pesticide formulations such as wettable powders. Tanks are typically made of **impermeable** plastic, or stainless steel.

Tanks should be designed for easy filling and cleaning. It is a requirement that filler caps be lockable. Further, all tanks are required to be fitted with a device that maintains an air gap to prevent back flow from the tank into a water supply. As an alternative, the fill hose can be equipped with an automatic back pressure shut-off device. The tank is also required by regulation to have an easy-to-read accurate sight gauge or other external means of determining the internal level.

The opening of the tank should be fitted with a cover that can be secured enough to prevent spills or splashes. The drain should open through the bottom of the tank so that the tank can be emptied completely. If the tank contains a pesticide, it must have a label including the **EPA** registration number of the pesticide, the owner of the equipment, and any applicable precautionary statements

AGITATORS

Very few products used for vector control require continuous agitation inside a spray tank. In-tank agitation may be accomplished by hydraulic or mechanical means. Hydraulic agitation is achieved by pumping some of the **solution** back through the tank. Mechanical systems achieve agitation through the use of some sort of paddle or propeller mounted on a shaft in the spray tank.

PUMPS

The pump is the heart of the sprayer. Most equipment used by vector control agencies are purchased as a unit, with a pump already installed. Choosing the correct pump requires matching it to the spray equipment to be used, and due consideration must be given to capacity, pressure, and resistance to corrosion and wear.

Gasoline engine-driven pumps have been supplanted by electric pumps in many modern spray systems, especially those using ULV spray techniques. Electric pumps are used in all new ULV mosquito control equipment, because these pumps are capable of the fine control over pressure and flow rate needed to meet label requirements for application rates. For other sprayers, there are many types of pumps available.

NOZZLES

The nozzle is probably the most critical element in a system for application of liquid pesticides. The nozzle determines many spray characteristics. **Nozzles affect the application rate, discharge shape (i.e., fine mist, cone, fan, etc.), droplet size, uniformity, pressure, and carry distance of the pesticide stream used for pesticide applications.** Poor nozzle performance can destroy the effective and efficient performance of the entire sprayer system. The position of the nozzle on the aircraft may also affect the product output. The differential airflow created by an aircraft may affect uniformity of applications. For nozzles to perform efficiently, they must be cleaned, repaired, and adjusted frequently. Damaged nozzles should be replaced with new ones promptly.

For any given pesticide application and any given spraying system, various characteristics of nozzles must be considered for nozzle selection and installation:

- Nozzle type
- Nozzle size
- Nozzle condition

For boom sprayers the following also may be important in achieving maximum effectiveness:

- Nozzle orientation
- Nozzle spacing on the boom
- Boom and nozzle elevation above the ground

TYPES OF SPRAYER NOZZLES

Many different types of nozzle are available commercially. Although not all of the following types are used in vector control operations, they are listed to provide an understanding of how nozzle characteristics can affect spray applications.

Flat Fan

This nozzle is used primarily on boom sprayers. It produces a nearly flat fan of spray in several selected angles and **deposits** an oval pattern on the ground. Less material is deposited at the outer edges, which requires the fan patterns to be overlapped to produce **uniform coverage**. This coverage depends upon proper spacing of the nozzles on the boom. When used from trucks or tractors, distance above the ground also has an effect on uniformity of application. These nozzles are used for **broadcast** or boom spraying in weed control work, and also in unpowered tank sprayers for work in home and garden situations.

Even Flat Fan

This nozzle also is used primarily on boom sprayers. It fills the outer portions of the spray pattern to produce even coverage across the entire width of the pattern. It is not designed for overlapping use on a boom. It is efficient for coverage of a given strip through the field as over a crop row. It is generally best for band spraying of herbicides in row crop work.

Cone

These nozzles are found commonly on unpowered backpack sprayers, unpowered tank sprayers, and boom sprayers. Spray is produced as either solid or hollow cone patterns. The cone angle contributes to better coverage of foliage and is one of the most popular nozzles for insect and disease control work.

Hollow cones are used primarily on unpowered backpack sprayers. They are designed for moderate to high pressures and are used where thorough coverage of crop foliage and uniform distribution is desired. There is little or no spray in the center of the pattern.

Solid cones are used for hand spraying, spot spraying, and moderate pressure **foliar applications**. The spray is well distributed throughout the pattern.

Flooding Or Impact

These nozzles are rarely seen in vector control use except for weed control applications. They have agricultural uses on farms and in home gardens, where they are used to spray liquid fertilizer **solutions**. They normally operate at low pressures with large droplets and can cover a wide area, so that it may by unnecessary to use a boom. This is an advantage on rough terrain or where many obstacles would hinder boom operation.

Offset

These nozzles lack the uniformity of the flat fan but can provide reasonably uniform coverage over wide areas for roadside and ditch bank weed control.

Atomizing

Atomizing nozzles produce a fine mist from liquid pesticides, and are the nozzles most frequently used in all types of ULV applications, both in ground and aerial spray operations. In comparison to nozzles used in compression sprayers, atomization nozzles can be very complex. Atomization is achieved in a variety of ways, depending upon the equipment used. In some the atomization is accomplished by rotation of the nozzle by electric motors, and others use wind-driven fans to produce rotation in the nozzle mechanisms.

Broadcast

These nozzles are used primarily from vehicles treating roadsides or rights of way with herbicides. They can be used either on boomless or boom-type sprayers. In the latter case a boom is used to extend the effective swath. The spray itself is in a wide flat fan pattern.

Solid Stream

In vector control, these nozzles are most often seen with handguns, hand can sprayers, and non-powered backpack sprayers when it is necessary to treat sites located at some distance from the operator. For larval mosquito control operations, best distribution of product is obtained by spraying upward and allowing the droplets to fall down onto the area. When compared to cone or solid cone nozzles, this application method allows much more rapid and efficient treatment of larger areas.

Adjustable

Adjustable nozzles are used frequently for vector control applications, and allow varying the spray pattern from a pinpoint stream to a cone. This type of nozzle is also used in small home garden sprayers. This type of nozzle is particularly useful when treating variable terrain. For example: The pinpoint stream nozzle may be used for a mosquito larval control application to target open areas in tulles or cattails in a pond, with the cone being used to treat flooded hoof prints along the edge.

NOZZLE CONSTRUCTION AND USE

Nozzles are subject to wear; they must be replaced before excessive wear occurs or they will fail to deliver the accurate amount and pattern of spray. The rate at which a nozzle wears depends upon several factors including: (a) the formulation of the material sprayed, (b) the nozzle design, and (c) the material used to construct the nozzle.

Characteristics of nozzle materials

- **Brass**: Inexpensive, but wears quickly from abrasion. Good for limited use.

- **Stainless steel**: Corrosion and abrasion resistant and relatively expensive.
- **Plastic**: Very inexpensive. Resist corrosion, but swell when exposed to some **solvents**. Not recommended for high pressure spray applications.
- **Tungsten carbide and ceramic**: Expensive, but provide long service. Highly resistant to abrasion and corrosion. Recommended for high pressure applications.

Selection, use, and maintenance of nozzles

- Select nozzles that will provide the desired droplet size, volume of flow, and spray pattern.
- After installation of new or repaired nozzles, properly calibrate the spray system to ensure proper application rates.
- Avoid spraying tank mixes of pesticides containing hard particulate matter such as sand or metal particles. This greatly accelerates nozzle wear, even with expensive nozzles.
- Always operate nozzles at the recommended pressure.
- Mount the nozzles securely so that their location, relative to the target, is maintained constantly and properly.
- Maintain nozzles in peak condition by periodic inspections, adjustments, and cleaning.
- **Never** use a pocket knife or other metal object to clean a nozzle. It will damage the precision-finished nozzle edges and ruin the nozzle performance. A round wooden toothpick is much better. Better still, remove the nozzle tip and back-flush it with air or water first before trying anything else.
- Don't blow through a nozzle by mouth, especially if it has been used for pesticide applications!

SPRAYER MAINTENANCE

Most troubles with sprayers can be traced to foreign matter that clogs screens and nozzles and sometimes wears out pumps and nozzles. Pump deterioration is brought about by ordinary use but is accelerated by misuse. The following suggestions will help prolong the useful life of pumps and sprayers.

1. **Use clean water.** Use water that looks clean enough to drink. A small amount of silt or sand can rapidly wear pumps and other parts of the sprayer system. Water pumped directly from a well is best. Water pumped from ponds or stock tanks should be filtered before filling the tank. To avoid contamination of water supplies, regulations require that all application equipment be equipped with an air-gap separation or back-flow prevention device to prevent pesticides from being siphoned back into the water source.
2. **Keep screens in place.** A sprayer system usually has screens in three places: a coarse screen on the suction hose; a medium screen between the pump and the boom or hose; and a fine screen in the nozzle. The nozzle screen should be fine enough to filter particles which will plug the tip orifice.
3. **Use chemicals that the sprayer and pump were designed to use.** For example, liquid fertilizers are corrosive to copper, bronze, ordinary steel, and galvanized surfaces. If the pump is made from one of these materials, it may be ruined by a single application of the liquid fertilizer.
4. **Never use a metal object to clean nozzles.** To clean nozzles, put on rubber gloves and then remove the tips and screens and clean them in water or a detergent solution using a soft brush. The orifice in a nozzle tip is a precision-machined opening. Cleaning with a pin, knife, or other metallic object can

adversely change the spray pattern and capacity of the tip. If no brush is available, use a round wooden toothpick.

5. **Flush sprayers before using them.** New sprayers may contain metallic chips and dirt from the manufacturing process. Sprayers which have been idle for a while may contain bits of rust and dirt. Put on rubber gloves and then remove the nozzles and flush the sprayer with clean water. Clean all screens and nozzles thoroughly before using the sprayer.
6. **Clean sprayer thoroughly after use.** After use, flush the sprayer with water or flushing solution to clear lines and nozzles to prevent corrosion and material drying in the system. Be sure to wear appropriate personal protective equipment during clean-up procedures.

> Be sure to discharge cleaning water where it will not contaminate water supplies, streams, crops, or other plants and where puddles will not be accessible to children, pets, livestock, or wildlife. The best way to use cleaning water is as a **diluent** in a sprayer tank for application of the same pesticide that was used in the sprayer before cleaning.

ADDITIONAL PARTS OF THE SPRAY SYSTEM

Each part of any sprayer must be working properly for the system to work efficiently. You should rely on your own judgment and the advice of experts such as pesticide dealers or sprayer manufacturers for details on the selection, maintenance, repair, and replacement of hoses, screens, filters, valves, gauges, and regulators, as well as for tanks, pumps and agitators.

CALIBRATION OF PESTICIDE EQUIPMENT

WHY CALIBRATE?

All pesticide labels contain information on allowable application rates. For a pesticide applicator to determine what **dose** is being applied, the application equipment must first be calibrated. There are many things that determine pesticide application rates. Some are related to the proper preparation of the tank mix, but many others are related to the operation and condition of the application equipment. Although power sprayers may produce consistent results when new, gradual wear of nozzles, pumps, and other components of the system will affect application rates. Further, no two pieces of equipment will behave in exactly the same way. For this reason, every time a vector control technician applies a pesticide, steps must be taken to ensure that the appropriate amount of pesticide is applied. Calibration of equipment is the means by which this is achieved.

Calibration of pesticide spray equipment is a legal requirement. It is a violation of state and federal regulations to apply a pesticide in any manner other than as specified on the label. Calibration of equipment is important to the success or failure of a pesticide treatment. It is a waste of time and money to apply any pesticide in an inefficient or ineffective manner.

WHAT IS CALIBRATION?

Calibration is the preparation of pesticide application equipment to ensure that a pesticide is applied appropriately, in the desired area, and with the correct amount of active ingredient. Calibration is the only accurate way to determine that the rate of application is consistent with the label requirements. Careful preparation of tank mix and proper operation of equipment during actual applications are also important factors to an effective and legal treatment.

Inaccurate pesticide application rates, spray patterns, and droplet size can all lead to ineffective and often illegal pesticide applications. These factors can lead not only to ineffective treatments, but also significant movement from pesticides away from the target area. **Studies have shown that three factors stand out in pesticide applications that do not conform to label requirements: inaccurate preparation of tank mixes, worn spray nozzles, and improper calibration of spray equipment.**

It is easiest to discuss calibration methods in connection with liquid forms of pesticides. However, dispersal of solid forms such as pellets or dusts follow the same principles, but with much different equipment and calibration procedures. These procedures will be covered toward the end of this chapter.

PRINCIPLES OF CALIBRATION

INFORMATION NEEDED

- The legal application rate as specified on the pesticide label
- Amount of liquid applied by the sprayer per unit of area at a given speed and pump pressure
- The amount of active ingredient contained per unit of liquid in the spray tank
- The capacity of the spray tank

ASSUMPTIONS FOR CALIBRATION

- The nozzles are in good repair, are of the proper type, and are made of the proper material
- Nozzle pressure, pattern, and flow rate will remain constant during calibration
- Speed of movement of sprayer (whether vehicle mounted or carried by technician) will be maintained constant during calibration

GENERAL PROCEDURES FOR CALIBRATION

Determining the Sprayer Output and Nozzle Output

There are various approaches to pesticide equipment calibration. Regardless of the approach used, the end result must always be a determination of the application rate, spray characteristics, and other specifications of the spray required by the pesticide label. An approach used for many types of ground and aerial applications using multiple nozzles mounted on a boom would include the following steps:

1. Read the pesticide label and record the allowable and recommended pesticide application rate.
2. Use water or appropriate diluent for pesticide to be applied for calibration.
3. Adjust nozzles to desired patterns and record nozzle pressures when operating.
4. Adjust speed of vehicle and record either MPH or engine RPM and transmission gear used.
5. Fill the spray tank with water.
6. Make trial runs spraying water at speed and pressure selected over one acre, or some fraction of an acre. When done, determine amount of water sprayed and calculate sprayer output in gallons per acre.
7. While still operating the sprayer at a selected pressure, catch and measure output for each nozzle for 1 minute, then calculate an average nozzle output in gallons per minute.
8. Count the number of nozzles to be used and measure the distance in inches between the nozzles on the boom.
9. From the sprayer output in gallons per acre, the average speed of the trial run in

MPH, and the nozzle spacing in inches, calculate a value for gallons per minute per nozzle based on the following formula:

Gallons per minute per nozzle = gallons per acre x MPH x nozzle spacing/5,940

10. Check the value you get from the calculation against the flow rate you determined from catching and measuring the output from the nozzles. If the two values are far apart (more than 10%), re-check your calculations. Another cause for a large difference might be an error in the test to determine the sprayer output in gallons per acre.

11. You also can perform this calibration in reverse, i.e., first determining average nozzle flow rate, then calculating sprayer output in gallons per acre using this formula:

Gallons per acre = (5,940 x gallons per minute per nozzle)/(MPH x nozzle spacing)

Remember that these values will be valid for only that speed, at that pressure, and at that nozzle output.

Some pesticide labels contain tables of values for calibrating spray equipment at various dilutions, application rates, and equipment speeds. If this is the case, calibration becomes much easier, and usually involves only checking the flow rates for individual nozzles. Unfortunately, not all labels contain this information, and the pesticide technician must do all the testing and calculations.

Calculation of the Tank Mix

Once you have calibrated the spray unit using plain water you will know how much spray the unit puts out per acre treated. From this you can figure out pesticide to add to the tank. To do this accurately, you will need to know:

- The application rate called for on the pesticide formulation label. Typically, this will stated as pounds per acre.
- The percentage of active ingredient in the commercial formulation.
- The capacity of the spray unit tank.
- The output of liquid (water) of the sprayer from the results of calibration
- The amount of tank mix desired, if less than a full thankful of pesticide.

From this information the amount of pesticide formulation needed for a full or partial tank of tank mix can be determined. An important consideration in doing this will be reconciling the units used for application rate of active ingredient (ai) specified on the label (usually by weight of ai) with the units used for sprayer output (usually liquid volume). For pesticide formulations that are mixed with water, the following formula can be used:

(Gallons of spray wanted) x (percent of active ingredient wanted) x 8.3/percent active ingredient in insecticide formulation

The figure 8.3 appears in the formula because this is the weight of a gallon of water in pounds based on a specific gravity of 1.00. Oils have lower specific gravities, and this must be taken into account if oils are used as a diluent. This information is usually contained on the label.

There are many variables involved in this process, and the calculations will depend upon the diluent used (if any), the size of the area to be sprayed, the type of equipment used, and other factors. Rather than furnish specific details to every situation a pesticide technician will face, several examples will be provided. Appendix 3 contains conversions for various units of measure and mathematical formulas used in pesticide equipment calibration. This information may be useful for calibrating equipment based on manuals written with **metric** units.

CALIBRATION OF EQUIPMENT FOR TYPICAL VECTOR CONTROL OPERATIONS

APPLICATIONS OF SOLID PESTICIDES

The principles of calibration are the same for applications of pellets, powders, and dusts, but the equipment will be different from that used for liquids. Some of this equipment will be large devices mounted on trucks or airplanes, and some will be hand-carried and powered. Both powered and unpowered devices use hoppers to hold the pesticide, and an impeller of some kind to discharge the material in a uniform manner. Discharge is controlled by a valve of some kind in both powered and unpowered units.

Instead of water, calibration can be with blank (inert) granules or other solids. This type of calibration will be on the basis of weight, so you can place a given weight of solid material in the hopper and measure the amount of material discharged on the basis of weight per unit of time and weight per unit of area.

Differences in speed between vehicle-mounted and human-carried equipment will be the same as for liquid sprayers, and the same methods of accounting for speed apply.

Although calibration is a legal requirement for all pesticide sprayers, there will be times when it is impossible to apply product in a consistent manner. One method of ensuring the appropriate application rate is to measure or estimate the area to be treated, and mix or load only enough product to treat the area appropriately. Begin by treating the area more rapidly than usual, ensuring that the area is completely covered. Then with any remaining product go back over the same area. If this method is used it is important that applicators avoid overexposing themselves to the pesticide.

APPLICATIONS FROM POWERED KNAPSACK SPRAYERS

This type of calibration will be similar to the general example given, except that movement speed will be more difficult to control, the areas sprayed will be smaller, and a single nozzle will almost always be used.

To determine the sprayer output rate, you would lay out an area representing an even fraction of an acre. A rectangle measuring 100 x 109 feet would be one-quarter of an acre. You can count the amount of water used to spray the plot, multiply by 4, and calculate the output in gallons per acre. You should also note the time in minutes it takes to spray the plot. From this you can calculate the gallons per minute of spray based on your walking pace. To check the calculation and the flow rate of the nozzle, you can catch and measure the output for one minute and record the result as gallons per minute. This should agree with your earlier value from walking the test plot.

Again, the calibration values will apply only for the nozzle used and the walking pace of application. The determination of amount of pesticide needed will be done as before, and will depend on the percentage of active ingredient in the commercial formulation, and the type of diluent (if any) used.

APPLICATIONS FROM UNPOWERED COMPRESSION SPRAYERS

This type of sprayer is used frequently for treatments of small terrestrial or aquatic sites for various kinds of pests, such as treatment of small ditches for control of mosquito larvae. Calibration of hand-carried and hand-pumped presents special challenges. Flow rate varies with pressure, and pressure varies widely with these kinds of devices. Some have pressure gauges, others do not. Also, since the travel speed of the sprayer will be the travel speed of the human carrying the sprayer, maintaining constant speed is difficult. Again, the end result of calibration is the same: to make sure the application conforms to the pesticide label requirements.

An approach that should provide a reasonable estimate for application rate will be similar to the methods used for the powered backpack sprayer. Measure a small plot that represents some even fraction of an acre (a plot 50 x 55 feet would be about 1/16 of an acre) and measure the time and number of gallons it takes to spray the plot. While spraying, walk in a manner that would be the same as you would walk making a real treatment, and keep the tank pumped up in a routine consistent with the actual application.

Calculate values based on gallons per minute and gallons per acre as before. Doing the trial spray several times will provide you an opportunity to check the consistency of your applications.

When doing the actual applications it will be necessary to estimate the size of your target area. In difficult areas where the spraying will be intermittent, you may have to keep track of the time spent while actually spraying with a stop watch.

ULV Applications From Air Or Ground-Based Sprayers

Calibration for applications using ULV methods is more complicated than most other types because sprayers must be calibrated for both flow rate and droplet size.

Flow Rate

Flow rate should be checked after all nozzles are inspected for damage and completely cleaned. One or more nozzles should be checked with the pump operating at the appropriate pressure. All lines and screens should also be checked for obstructions to make sure insecticide will be free-flowing. If a battery-powered electric pump is used, the battery should be first checked to make sure it is fully charged.

The flow rate of the nozzles can be controlled at the pump with most equipment by adjusting a knob or screw at the pump. To measure flow rate, either water or mineral oil should be collected in a graduated cylinder for a set period of time. This should be repeated several times and an average value determined for each nozzle. Finally, and average value for all of the nozzles are determined and recorded.

Droplet Size

The range of droplets produced using ULV equipment is characterized by a measurement called **volume median diameter** (VMD). Labels for pesticide formulations designed for ULV applications will contain information on the required range of VMD values for both ground and aerial application. As an example, the label for Clarke Biomist® 31+66 ULV specifies that for ground applications, the VMD of droplets must fall with a range of 8 to 30 microns (µm) and that 90% of the spray must contain droplets of less than 50 µm. This sounds like an incredibly difficult measurement and calculation task for insecticide technicians, but modern analytical equipment is available that makes the measurements and provides complete profiles for the droplet spectrum. The DC-III (KLD Labs, Inc., Huntington Station, NY) uses what is known as a "hot wire" approach.

Other analytical units, such as the VisiSizer from Oxford Lasers perform the same functions, but with laser beams that result in digital images of the pesticide stream that are fed into a computer for complete analysis.

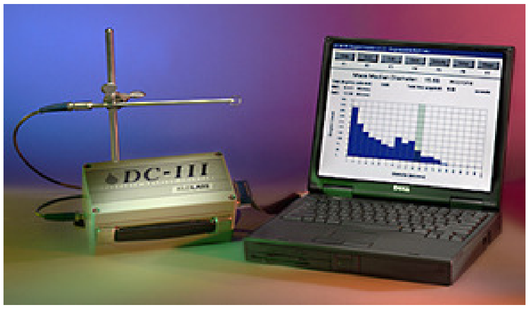

Fig. 8.5 The DC-III Analyzer (KLDLabs, Inc.)

Older manual methods involve waving a glass microscope slide by hand through the pesticide stream and then examining the slide under a microscope. Upscale approaches to this method use mechanical rotating devices instead of a human hand. In either case, the slides are examined under a microscope and the droplets then are measured and counted by hand.

If droplets are not within the desired range for the application, various adjustments must be made, depending upon the method being used to break up the pesticide into droplets. In many units, the droplets are produced in specialized nozzles that use streams of high pressure air to shear the droplets off the material as it enters the nozzle. To adjust the range of droplet sizes, the speed and volume of air moving past the nozzle are adjusted. Generally, the higher the speed and volume of air, the smaller will be the droplets.

For after-spray assessments, these and other methods, such as the use of dye cards placed in the path of the sprayer, are used to collect spray particles. These are then analyzed in the laboratory to determine if the proper droplet sizes were achieved in an application.

Frequency of Calibration

For ULV sprayers, flow rate should be checked regularly – depending on how often the machine is used. Droplet size should be tested at least annually prior to the spray season, and after any repairs to the machine. In the unusual event that the ULV spray nozzle itself is damaged, it must be professionally machined or replaced.

OPERATION OF SPRAY EQUIPMENT AFTER CALIBRATION

Since consistent and uniform distribution of pesticide is necessary for successful applications it is necessary to operate spray equipment properly. This means keep vehicle speed as constant as possible. Remember that at a given pump pressure, if you reduce speed significantly you will increase pesticide application rate significantly. Anyone who has pushed a fertilizer spreader around a lawn knows what happens if you stop for a break and fail to close the hopper!

All modern power equipment includes pressure gauges for pumps. Most pressure gauges are located within easy view of the driver. Observe pressure readings frequently and make necessary adjustments to maintain constant pump pressure throughout the application.

If you see evidence that the application isn't going correctly (e.g., if pump pressure is fluctuating wildly) stop and check the equipment, and if necessary, re-calibrate.

Chapter 9

PESTICIDE APPLICATION PROBLEMS

In addition to the safety problems associated with the preparation and application of **pesticides**, there are several important problems related to pesticide use that should be understood by every **applicator**. These problems include pesticide **drift**, pesticide **residues**, **phytotoxicity**, destruction of beneficial species of animals and plants, resistance of pests to pesticides, and environmental pollution. There are many ways in which these undesirable effects can be reduced or eliminated. Each depends upon knowledge of the proper handling and use of pesticides, the components of the environment **susceptible** to contamination, the pesticides most likely to cause contamination, and preventive measures.

PESTICIDE DRIFT

Except for ultra low volume (ULV) spraying to control **adult** mosquitoes, drift is an undesirable side effect associated with both aerial and ground pesticide applications. Spray drift is defined as airborne particles produced during application of a pesticide moving outside the intended treatment area. The severity of drift depends on the physical form of the material, the method of application, weather conditions, and to a lesser degree, movement of the substrate to which the **product** was applied (both soil and water).

Drift is a desirable and necessary part of an ULV application. In fact, pesticide **labels** specify that ULV applications must be done during weather conditions that favor pesticide drift (temperature inversion or lateral winds below 10 MPH). In a ULV application, the longer the effective drift of the product, the greater the efficacy.

For other pesticide applications, the formulation of the pesticide is a significant factor. **Dusts** are most likely to drift and granules least likely. **High pressure sprayers** are more likely to produce fine droplets that are more likely to drift than low pressure sprays.

A variety of other factors can affect the amount of drift. When spraying liquid **formulations** of pesticides, the nozzle and pump pressure have the greatest influence on subsequent drift. Improper or worn nozzles or excessive pressures cause the spray to be produced in a form which drifts readily.

The rate at which a drop of liquid falls through the air depends upon the size of the droplet. Very small droplets fall very slowly. These small droplets can drift for miles before they reach the ground. The method and amount of material applied also influences the **hazard** of pesticide drift. Small amounts applied by hand from the ground are rarely involved in drift problems. Spray from ground **air blast** sprayers is highly subject to drift. Aerial applications of large quantities of pesticides always present the possibility of significant drift.

A second form of drift occurs when pesticides **evaporate** during and after application. Certain **herbicide** formulations may volatilize and cause damage to plants miles from the point of application. A few herbicide formulations may drift as a result of evaporation following application; use of these may be restricted in many areas.

Drift should be avoided because:

- It wastes resources, including pesticides, fuel, and technician time.
- It spreads pesticides into the surrounding environment where they

may become **illegal residues** on food crops, cause health problems, damage wildlife, and have other undesirable effects.

- It can damage **sensitive** crops.
- It has been the subject of many damage claims for crop losses. Drift can be a severe problem and should be taken into consideration before making any type of pesticide application

Whenever a pesticide chemical is applied, some of the chemical becomes a deposit on or in the treated crop, animal or object. The pesticide may remain in its original chemical form or it may be altered chemically by **weathering**, metabolic **degradation** or other processes. In any case, the quantity of material remaining is called a **residue.** Residues may result from direct application, from drift from nearby fields, from uptake from contaminated soil, or from other sources. In some situations residues are desirable and produce prolonged effective pest control, as in the control of certain public health and **structural pests**. In other situations, however, residues represent a source of unwanted and illegal contamination — for example, when residues exceed legally determined limits on food or feed crops at harvest.

PESTICIDE RESIDUES

Pesticide residues are generally meant to include pesticides that are detectible in or on places other than their intended target. Fresh water reservoirs, stream bed sediments, and harvested food would be examples of places that would be tested for pesticide residues. Needless to say, if high levels of residues were found to occur in such situations, few would consider the test results to be a good thing. Pesticide residues are usually measured and tolerances expressed in parts per million (ppm) to parts per billion (ppb) on a weight basis. One ppm is one **milligram in a kilogram**, or one ounce of salt in 62,500 pounds of sugar, or one pound of pesticide in one million pounds of raw agricultural commodity. In some instances modern analytical chemistry techniques can test residue levels below one ppb.

The residue levels allowed on food crops at harvest are legally set by the federal and state regulatory agencies and are called tolerances. **Tolerances** are simply the maximum amounts of pesticide permitted to be present on or in raw agricultural commodities. These tolerances represent levels of pesticide residues which scientists have determined may safely remain on the food crop without injury to the consumer. Tolerances vary according to the pesticide and the crop.

The California Department of Pesticide Regulation regularly inspects and analyzes samples of fruits, vegetables, feeds, dairy products, meat and other produce to be certain pesticide residues do not exceed legal tolerances.

When **pesticide tolerances** are found to be exceed legal tolerances, the agricultural commodities involved may be seized and destroyed. Ordinarily, such situations would arise from the application of agricultural pesticides on crops, but it could happen even where pesticide applications are not specifically targeted at a crop pest, such as the application of pesticides on rice fields for mosquito control.

Before allowing the use of a pesticide on food crops, **EPA** sets a tolerance. If no tolerance has been set for that pesticide on that crop, the pesticide cannot be legally applied on the crop. Some pesticides may be considered "safe" by EPA, and they would be exempted from a tolerance.

SOME FACTORS AFFECTING RESIDUE LEVELS

PERSISTENCE OF COMPOUNDS

Most **organochlorine** pesticides (e.g., DDT, chlordane) are very **persistent**. Most of the **organophosphates** (e.g., parathion, malathion) and pyrethroids are much less persistent. **Pyrethrins**, and **carbamate** pesticides are nonpersistent. Some factors that influence the persistence of a chemical and the possibility that residues may remain are:

- The amount of chemical applied
- The formulation
- The pH (acidity or alkalinity) of the water **diluent** and of the target tissue, soil, or water.
- The nature of the surface to which it is applied
- **Exposure** to weathering from wind, rain, etc.
- Chemical breakdown from high temperatures and humidity
- Photochemical reactions from sunlight
- Biological reactions.

If public health pesticides are applied properly and in accordance with label restrictions for applications around food crops residues on or in the crop should never be a problem.

CERTIFIED ORGANIC CROPS AND FARMS

Organic farming is a form of agriculture which does not permit the use of synthetic fertilizers and pesticides, plant **growth regulator**s, livestock feed **additives**, and genetically modified **organisms**. As far as possible, organic farmers rely on crop rotation, green manure, compost, biological pest control, and mechanical cultivation to maintain soil productivity and control pests.

Organic agricultural methods are internationally regulated and legally enforced by many nations, based in large part on the standards set by the International Federation of Organic Agriculture Movements, an international umbrella organization for organic organizations established in 1972. The United States Department of Agriculture also tracks organic policies and procedures nationally.

Vector control technicians working near these farms need work closely with the landowner to prevent vectors from coming from the property, and to avoid jeopardizing the organic status of the crop. If a pesticide excluded for use on organically produced commodities is accidentally applied to an organic crop, the crop may no longer qualify to be sold as organic. If this occurs in connection with a vector control operation, the producer can pursue a settlement from the vector control program for his loss. While that particular harvested crop may no longer be considered organic, the farm will still qualify as "certified organic". If there is repeated contamination by any party, the farm will lose its organic certification and must wait at least 3 years before it may apply for organic certification again.

With the growth of organic farming in California, vector control operations will face increasing challenges in applying pesticides in the vicinity of organic farms. This will involve developing innovative methods of preventing vector problems from occurring on and adjacent to organic farms while respecting the landowner's desire to maintain organic practices. The increasing acreage of organic rice in the Central Valley is an example of a particularly difficult challenge.

PHYTOTOXIC EFFECTS OF PESTICIDES

Phytotoxicity is the injury or death of a plant due to exposure to a chemical.

Plants may be injured or killed by various kinds of chemicals, including salts, fertilizers, or pesticides. Sometimes, plant injury is intentional, as when an herbicide is applied to a weed. In other cases, the plant injury is an accidental side effect of pesticide use. Phytotoxicity can effect any part of a plant, including roots, stems, foliage, blossoms, or fruit.

The degree of phytotoxicity caused by pesticides may vary in response to a number of factors. Some **toxicants** (**active ingredients**) are particularly damaging to plants. Other components of the pesticide mixture, such as the diluent, may cause plant damage. The plants themselves may vary in **susceptibility** to injury by various chemicals. The phytotoxic reaction may vary with the species of plant, with the age of the plant, or with the weather at the time of exposure.

The manner in which a chemical is applied may determine whether or not injury will occur. For example, excessive pump pressures while spraying may cause physical injury to the plant or drive the chemical into the plant tissues. Excessive concentrations of a chemical may cause plant damage. Certain combinations of pesticides may cause phytotoxic reactions. Some pest problems require two or more chemicals combined in the tank mix. Mixtures are used commonly with great success. However, some chemicals are not compatible with others and one of the results of this incompatibility may by severe phytotoxicity. Many herbicide labels list other products with which they may be combined.

DAMAGE TO BENEFICIAL INSECTS

The efficient production of many crops, including fruits, vegetables, forage, and seeds, would not be possible without the activities of honey bees and other pollinating **insects**. In California, the beekeeping industry maintains millions of honey bee colonies. Each year honey bees pollinate billions of dollars worth of crops in the state.

Over the past 100 years or so the honey bee industry has sustained serious losses from pesticide applications. Recently; pesticide poisoning has come under suspicion for reductions in honey bees in the USA. Some agricultural pesticides used currently are known to pose a significant hazard to bees. Vector control applications are ordinarily done in a manner that minimizes risk to bees and other beneficial insects.

In addition to pesticide exposure, honey bee colonies are at risk from a variety of **parasites**, **pathogens**, marauding **mammals**, and other factors. To protect these valuable insects from losses due to pesticide poisoning it is necessary to know where colonies are located before starting a pesticide application, and to protect them in some way. Moving colonies to areas far from the possibility of drift and avoiding the use of pesticides known to be especially toxic to bees are two ways to minimize damage. If public health pesticide applications are planned for areas known to be close to bee colonies, it is also a sound policy to warn hive owners in advance of the applications so they have an opportunity to protect them.

There are other pollinating insects that may suffer damage from pesticide applications, such as alkali bees and other wild bees. Wild bees are not in hives, but are present in a variety of nest types. This complicates their protection from pesticides.

Other insects are beneficial because they prey on or parasitize pests. There have been many studies on the effects on **non-target** organisms of pesticides in a variety of settings. Your local extension specialist can provide you with copies of reports of this kind of research.

By definition, pesticides that harm non-target organism populations significantly are non-selective. If use of a **non-selective pesticide** is considered essential, it must be justified based on the relative benefits balanced against the relative harm. In the case of public health pesticides, the threat to human health is a necessary consideration.

The ideal pesticide would be selectively nontoxic to bees and other beneficial organisms, while toxic to a specific pest. Few products available for adult mosquito control meet this ideal, but several larval mosquito control products and many herbicides are selective. For adult mosquito control and other pesticide applications, the best compromise must be found.

HONEY BEE PROTECTION

For vector control technicians, protecting domestic bees is primarily a concern when doing ULV adult mosquito control. The pesticides most commonly used for these applications (pyrethrins and pyrethroids) are toxic to bees. However, they are applied in minute quantities (often less than 1 ounce per acre of total volume of material) during the evening or early morning when bees are **inactive**. Taking the reasonable precaution of turning off the sprayer while passing the hives should be adequate to prevent any mortality in the bees from the product.

Bees are readily poisoned by organophosphates and many agricultural pesticides. When a pesticide known to be harmful to bees is used near bee hives or to any cropland where honey bees are working, special procedures must be followed. Under California law beekeepers may request notification of intended pesticide usages, and the applicator is required to provide such notice.

Vector control agencies that have signed the Cooperative Agreement with the California Department of Public Health are exempted from regulations that require notification of pesticide applications. Despite this regulatory **exemption**, vector control agencies should work closely with local beekeepers to protect their bees. Vector control technicians and agencies should also remember that they are not exempt from potential damage claims for lost bees or hives, nor are they protected from landowners claiming indirect damage to crops. It is thus only reasonable for vector control agencies to keep bee keepers apprised of ULV mosquito control applications so keepers can move or cover hives if they choose.

In some areas centralized private organizations operate a beekeeper notification program. Bee notification maps are maintained and each day copies of beekeepers' requests for notification from the County Agricultural Commissioner are received. Then interested bee keepers are notified by a single telephone call of all intended applications within one mile of their hives.

RESISTANCE TO PESTICIDES

Pesticide resistance is the ability of pests to avoid the **lethal** effects of pesticides. Certain populations of pests use one or more different **physiological** or behavioral defense mechanisms to withstand **doses** of pesticides that previously were lethal to the pests. This can happen through spontaneous **mutations** in populations resulting in genes that confer pesticide resistance, or because a small proportion of the population carries a gene for pesticide resistance naturally. In either case, resistance develops gradually to the point where pesticide applications begin to fail after repeated exposure to the same pesticide. This is because the parts of the population that carry the gene for susceptibility are killed off, and soon, a disproportionate segment of the population carrying the gene for resistance predominates. This can be an unintended effect of using pesticides. Resistance in numerous pests of public health importance has occurred to a variety of pesticides. For mosquitoes and flies, resistance to organochlorines and organophosphates has been particularly common.

Selective pressure is the repeated exposure of a population of pests to treatments of the same pesticide over time resulting in a change in the genetic makeup of that population. In this case, the population is selected to favor resistant genes at the expense of susceptible genes, and the population becomes resistant to that pesticide. Because of the nature of population genetics, the population never becomes completely resistant, but the frequency of individuals have susceptible genes becomes very small.

Knowing the mechanisms of development of pesticide resistance is important to developing strategies to avoid creation of resistance in pest populations. The basic principle is the preservation of susceptible genes in pest populations, and the endeavor to do this is named **pesticide resistance management**.

Usually, when a pest population becomes resistant to one pesticide it can still be controlled by other pesticides, especially pesticides in a different family of chemicals. Occasionally, resistance to pesticides other than the pesticide responsible for resistance may occur. This is called **cross-resistance.** Its occurrence is usually seen among chemically related pesticides where the **mode of action** is identical or very similar.

RECOGNIZING RESISTANCE

Not all pest control failures are the result of resistance. Improper pest control practices may be at fault. However, if the material was timed and applied properly at the recommended rate and no other important factors (such as unfavorable weather) have interfered with the pesticide application, resistance should be considered.

Early signs of resistance may sometimes be recognized in the field. These include increasing difficulty in controlling a pest, increasing numbers of formerly minor pests, and increasing trouble with insect-transmitted disease. Developing resistance can be very subtle and may go unnoticed for a time; it may appear in certain locations or breeding sites. Suspected resistance should be reported to your supervisor immediately since early detection may make it possible to delay resistance by the application of counter measures.

RESISISTANCE MANAGEMENT

Based on the genetic principles of development of pesticide resistance in pests, a number of principles have evolved over the years that when implemented can either delay resistance, or avoid it entirely. Some of these principles are:

- Avoid under-dosing in pesticide applications. If this is done repeatedly it encourages survival of individual pests carrying genes for resistance, especially when the effects of the gene are not absolute (protects only partially).
- Do not always treat a given population with the same pesticide. Switch to other products periodically. This is called pesticide rotation.
- Test populations of vectors for evidence of resistance, and when it is detected switch to alternate pesticides.
- Avoid slow-release applications where pest populations are exposed for long periods of time to sub-lethal doses of one pesticide.

- Combine pesticide applications with other forms of pest management such as **biological control**, habitat alteration, and use of **biorational pesticides**. The use of biorational pesticides is not a guarantee that resistance to these products will not occur, but resistance to biorational pesticides have been far less common than to conventional pesticides.

UNWANTED ENVIRONMENTAL EFFECTS

Unwanted pesticide chemicals in air, soil, water and vegetation are a form of environmental pollution. Accumulation and storage of pesticides in plants and animals from long lasting **insecticides** such as DDT was once a form of environmental pollution. This bio-storage and bio-accumulation of pesticides does not occur with modern insecticides that degrade rapidly under ambient conditions and are metabolized quickly by living organisms.

As the population of the world increases, our environment is becoming more and more **polluted**. Pesticide use contributes to this condition, especially in large-scale agricultural operations. Care in the use and disposal of pesticides will aid in reducing environmental pollution. In order to accomplish this, people who use pesticides should have an understanding of the fate of these chemicals after they have been released into the environment.

Whenever pesticides are used some proportion of the amount applied fails to reach the target. Furthermore, the material eventually reaches the general environment in either its original form or in the form of a breakdown product. Each pesticide has its own unique chemical and physical **properties** and therefore its own unique behavior in the environment. However, when the effects of pesticides on the environment are considered as a whole, it is possible to make a few generalizations.

ATMOSPHERIC POLLUTANTS

Pesticides may enter the atmosphere by several methods. They may be blown away with soil particles in cultivation or as smoke from burning materials. A major source of atmospheric pesticide pollution is from improper application of sprays and dusts. Spraying during windy periods or with the wrong or improperly maintained equipment are major contributors to this problem. Once in the atmosphere, pesticides are either degraded to other compounds or trapped in rain, fog or dust. They eventually fall to earth.

SOIL POLLUTANTS

Very few persistent pesticides are used in vector control operations any more. Because some weed control projects may involve the use of long-lasting herbicides, public health pesticide applicators should be familiar with the ways persistent pesticides can cause pollution of soils.

Many pesticides are applied in areas with vegetation of some kind. If persistent pesticides are applied to plants, some of the material reaching the ground during the application and some of the material contained in harvest residues may be incorporated into the soil. Long-lasting pesticides also may be applied directly to the soil to control insects, weeds, **fungi** and **nematodes**. In this case most of the material reaches the ground immediately and in unchanged form; then it may be incorporated into the soil through agricultural operations.

When excess or repeated applications of inorganic or very persistent **organic pesticides** are made, soil residues can build up until they become a severe problem. Residues of hundreds of pounds per acre have accumulated in some soils. Pesticides in the soil may cause illegal residues in root crops or they may be translocated into the tops of plants. They may also leach into nearby surface or groundwater supplies or they may cause undesired phytotoxicity

Once in the soil, organic pesticides may be rapidly broken down by natural processes or they may remain unchanged for years. Pesticides in soils break down through chemical reactions which depend on the structure of the soil, its moisture content, its pH, salinity and other factors. Many organic pesticides are broken down by the action of microbes in the soil. Microbial decomposition depends on the temperature, moisture, and organic matter in the soil, as well as on the chemical nature of the pesticide itself. Cultural practices can have an important effect on the longevity of pesticides in soils. Proper cultivation and irrigation practices can speed removal of unwanted pesticides from soil. Pesticide labels often contain useful information on prevention of soil pollution problems associated with the material.

WATER POLLUTANTS

Pesticides occur in water as intentional and unintentional additives. Intentional applications are made to control aquatic organisms including mosquitoes and gnats, algae, snails, weeds and "trash" fish. Use of pesticides in water presents special hazards to plants growing in or irrigated with the water, to fish and other animals living in the water,. Specific hazards include non-target toxicity and biological oxygen demand created by decaying vegetation. Fish, animals and people who might drink or bathe in the water may be at risk. Therefore, it is extremely important that those planning to apply pesticides directly to bodies of water **be completely familiar with and follow label directions pertaining to any material being used in or around water - including posting notice of the application when required by the product label.**

Unintentional water pollution has resulted from drift, drainage from treated soils, accidental applications, unintentional spills, and from sewage effluents. Pesticides in the atmosphere are washed down by rain and reach streams, lakes, and the ocean. Other pesticides reach the **surface waters** through **runoff** from soils and from industrial waste disposal. At times pesticides have been accidentally sprayed onto bodies of water, where they cause extensive pollution. Such contamination is usually preventable. Pesticide spills are usually of limited local importance and, because of their emergency nature, are frequently dealt with very effectively. Sewage effluents are generally associated with manufacturing processes and are of little direct concern to the pesticide applicator.

BIOTIC POLLUTION

The direct effects of pesticides on wildlife depend on the kind and formulation of the pesticide, the **target pest** species, and on the species of wildlife exposed. For example, pyrethrins are highly toxic to fish, but virtually non-toxic to mammals or birds. Direct effects on wildlife also depend on the exposure of the animals to the pesticide; pesticides with long residual actions may cause wildlife losses for extended periods. On the other hand, pesticides with short residual effects may cause large losses but only for a short time.

The largest potential for indirect effects to wildlife is from vegetative changes that can improve or degrade habitat for many species of wildlife. Changes in vegetation or insect populations can significantly alter the food resources available to wildlife species.

Recently, residual accumulations of PBO, a synergist commonly used to increase the effectiveness of pyrethrins and pyrethroids, has been detected in stream bottom sediments. Although non-toxic itself, PBO may have the potential to make other pesticide residues in stream bottoms more toxic to aquatic organisms. This has raised the question of a potential role for PBO as a harmful stream pollutant.

MINIMIZING ENVIRONMENTAL EFFECTS

While each of us wants to protect the environment, we need to remember that pesticides are necessary tools in managing vector and pest populations. Each pesticide label contains a warning of known environmental effects of the active ingredient. Careful attention to label directions will aid you in the selecting and using of all pesticides in ways that minimize adverse environmental effects.

Remember — apply pesticides:

- Only to identified pests
- Only when necessary
- Only where they are needed
- Always at rates permitted by the label
- Only in situations allowed by the label

Chapter 10

PESTICIDES AS HAZARDOUS WASTE

Hazardous wastes are wastes with **properties** that make them dangerous or potentially harmful to human health or to the environment. Some **pesticides** are considered by **EPA** to fit this definition, and are thus subject to laws and regulations regarding their proper handling, transportation, and disposal (Tables 10.2, 10.3).

CLASSIFICATION OF HAZARDOUS WASTES

A number of different federal and state agencies have enforcement responsibilities in regard to various aspects of hazardous waste management. The US Department of Transportation enforces regulations for movement of hazardous wastes. In 1976 the US Congress passed the Resource Conservation and Recovery Act (RCRA), which directed that EPA develop and implement a program to protect human health and the environment from improper hazardous waste management practices. EPA has done this. Details of their programs can be found at http://www.epa.gov/osw/hazwaste.htm. In California, the Department of Toxic Substances Control (DTSC) (http://www.dtsc.ca.gov/) is responsible for hazardous waste information and enforcement.

Listed waste

EPA publishes lists of specific wastes that they consider hazardous. The lists are:

- F List (non-specific source wastes). This list consists of materials from common manufacturing and industrial processes such as cleaning **solvents**.
- K List (source-specific wastes). These are certain wastes from specific industries such as petroleum refining and pesticide manufacturing.
- P List and U-List (discarded commercial chemical **products**) include specific chemical products in an unused form. Some pesticides and pharmaceuticals become hazardous waste when discarded.
- M List (discarded mercury products; California). Included in this list are items such as fluorescent lamps and mercury switches.

Characteristic waste

In addition to the EPA list, there are four criteria that are considered by them for chemical substances that may not be on one of their lists:

- Ignitability. These are substances than can create fires under certain conditions because they are spontaneously combustible, or have flash points less than 140°F. Waste **oils** and used solvents may meet this criterion.
- Corrosivity. Corrosive wastes are acids or bases (less than 2 or more than 12.5, respectively, that are capable of corroding metal tanks, drums, and barrels.
- Reactivity. Reactive wastes are substances that are unstable under normal conditions. They can cause explosions, toxic **fume**s, gases, or vapors when heated, compressed, or mixed with water.
- Toxicity. Toxic wastes are harmful or fatal when **ingested** or absorbed (e.g., those containing mercury or lead). There are 8 characteristics of toxicity defined in California, and if a waste meets even one of the 8, it is considered a toxic hazardous waste

(http://www.dtsc.ca.gov/HazardousWaste/upload/HWMP_DefiningHW1.pdf).

EPA has extensive information on hazardous substances on their website, listed above. Pesticide **applicators** should note that certain pesticides would fall under the category of hazardous waste based on several of the criteria listed here.

Here is a general rule concerning what is and what is not a hazardous pesticide waste, aside from the criteria already covered: if the material in question contains any concentration of pesticide that can no longer be legally used, it must be considered a hazardous waste. If the material in question is considered no longer desirable as a pesticide, such as rinse material from containers and spray equipment, left-over spray solutions, excess pesticides, and cancelled/suspended pesticides, it must be disposed of as hazardous waste.

If you are uncertain as to whether or not some quantity of a pesticide substance qualifies as a hazardous waste, you may:

1. Call the California DTSC at 916-327-4499
2. Send an email to the California DTSC: wasteclass@dtsc.ca.gov
3. Examine Material Safety Data Sheets for statements concerning it status as a hazardous waste
4. Read the pesticide **label** for information on its status
5. Write or call the formulator or distributor for information

ORIGIN OF HAZARDOUS WASTES IN VECTOR CONTROL OPERATIONS

The most obvious origin of hazardous wastes related to vector control operations is pesticide applications. Some of the sources include empty pesticide containers containing hazardous residues, rinse water used to clean spray equipment and vehicles, pesticides remaining in sprayer tanks after an application, and unused stocks of outdated and possibly suspended pesticides. Another source of hazardous wastes is the repair and maintenance facility maintained by most mosquito and vector abatement agencies. In California, used motor oil is considered a hazardous waste. Solvents and other fluids used in connection with vehicle maintenance and repair may also fit the classification of hazardous.

One of the keys to management of hazardous waste is to examine the activities of an agency to determine which of them may be generating waste, and how much is generated on average per month.

PROPER MANAGEMENT OF HAZARDOUS WASTES

Most mosquito and vector control agencies will generate waste that will qualify as hazardous. The US EPA has established categories for agencies that generate hazardous waste based on the amount of hazardous waste generated each month (Table 10.1). These same categories have been adopted by the California DTSC. It is important for agencies engaged in vector control operations to know the amount of waste they generate, because the rules for disposal of hazardous waste vary according to the category. This primarily applies to how long hazardous waste can be stored before it must be disposed of as there is an increased risk potential associated with storage of large quantities of these waste.

Table 10.1. EPA Hazard Generator Categories

Hazardous Waste Generated per Month	Category Name and Maximum Allowed Accumulation time
Less than 220 lbs (about half a drum)	CESQG (Conditionally exempt from requirement)
220 lbs –2,200 lbs (up to 5 drums)	SQG (Small Quantity Generator) 180 days (270 days if waste to be transported 200 miles or more
2,200 lbs or more (over 5 drums)	LQG (Large Quantity Generator) 90 days

CONTAINERS USED TO COLLECT HAZARDOUS WASTES

Hazardous materials can be placed in their **original containers** temporarily, but the most common containers used to store hazardous wastes prior to their disposal are 55-gallon steel or plastic drums and inner liners from these drums.

If you have dedicated containers for pesticide hazardous waste, they must contain the following label:

HAZARDOUS WASTE
Federal Law Prohibits Improper Disposal If found, please contact the nearest police, public safety authority, or the US EPA

Other information that should be placed on waste containers include the date waste was first put in the container, the federal waste code numbers, and the type of waste contained in the container. Even if the waste is not classified as hazardous waste, it is a good practice to label the container with the waste material it contains.

EMPTY CONTAINERS

Regulations that address the management of empty pesticide containers are very complex. The DTSC has prepared a fact sheet “Managing Empty Containers” that contains an extensive question and answer section. This fact sheet is available on their website.

California regulations recognize two categories of containers that are exempt from management rules for hazardous waste: (1) containers that once contained waste that does not qualify as hazardous, and (2) containers that meet the definition of “empty” (see below) and have been subjected to approved management practices. Containers that are exempt can be disposed of at any appropriate solid waste facility.

From the standpoint of management of hazardous wastes, “empty” containers are defined as containers that once held hazardous materials or hazardous wastes and have been emptied by the generator (in most cases the vector control agency that used the pesticide) as much as is reasonably possible. In practice, this means inverting the container until no more liquid or solid material pours out. However, because of the concern that containers that fit the definition of “empty” may still contain some residual hazardous materials that could cause significant harm, they are still not considered non-hazardous unless approved management practices are followed.

Containers that held liquid pesticides classified as **acute** or extremely hazardous waste must be triple-rinsed with a solvent capable of removing the material before they can be considered ready for disposal. It would be unusual for most vector control agencies to use pesticides fitting the latter category.

Containers that held solid pesticides, or pesticides that have become viscous and pour slowly, or have dried out or otherwise become caked, must be cleaned using various methods, such as scraping, in addition to rinsing to remove all pesticide residues.

Management practices required are flexible, depending upon the way empty containers are handled by a particular agency. Some may return empty containers to the original distributor; others may ship containers to a company that reconditions them. Empty containers of 5 gallons or less can be disposed of at a solid waste facility.

LARGE CONTAINERS

Some mosquito and vector control agencies use special underground tanks to collect hazardous wastes such as rinse water. Underground storage tanks are not considered containers, and their management is covered under other regulations. Bulk containers of 110 gallons or more also are controlled by a different set of regulations.

STORAGE OF CONTAINERS FULL OR PARTIALLY FULL OF PESTICIDES

Containers of pesticides over time can deteriorate to the point where they can rupture, leak, rust, and otherwise lose their original integrity. Especially if pesticides are stored over long periods of time (years) they should be periodically inspected for signs of deterioration, and if leaking containers are found, their contents should be transferred to a new container.

Containers should be kept closed at all times. If containers are used to contain waste, self-closing funnels should be used to add waste. Waste pesticides should never be allowed to **evaporate**.

Pesticides should always be compatible with the material the container is made of. If the waste is corrosive, high density plastic containers should be used. Wastes that are reactive (e.g., acids and bases) should never be kept in the same container.

Containers for waste pesticides should be stored indoors. Adequate aisle space and ventilation should be provided. This makes periodic inspections for leaks and container deterioration easier.

Ignitable and reactive pesticide wastes should be stored at least 50 feet from property boundaries.

Pesticide wastes, depending upon the amount of waste generated per month, have legal time limits they can be stored before disposal.

REQUIRED NOTIFICATIONS OF HAZARDOUS WASTES

Agencies that generate pesticide hazardous waste should designate an emergency coordinator. This person must know what to do in case of a poisoning, fire, spill, or other emergency, and should be available 24 hours a day, 7 days a week. The following information should be clearly posted in a prominent place, such as near a telephone in the main district office, or near a telephone in the proximity of the storage site for pesticide hazardous wastes:

- Local fire department number
- Emergency Coordinator’s name and telephone number
- Locations of fire alarms and fire extinguishers
- Location of pesticide spill control materials

PESTICIDES NOT CLASSIFIED AS HAZARDOUS WASTES

- May be disposed of as regular solid waste or trash.
- Are regulated by California law

- Must be disposed of according to instructions contained on the product label
- Must be disposed of in a careful manner

PROPER TRANSPORTATION OF HAZARDOUS WASTES

In California the transportation of hazardous wastes are regulated by the California Department of Toxic Substances Control (DTSC), and no hazardous wastes may be transported without first getting a permit from DTSC. Because of the complex and expensive requirements for permission to transport hazardous wastes, most mosquito and vector control districts contract with a licensed operator to remove, transport, and dispose of hazardous wastes.

Those who believe they would like to transport and dispose of hazardous wastes in-house should refer to "Hazardous Waste Transporter Requirements", August 2007, available on the DTSC website. After reading the daunting requirements, few pesticide technicians will want to pursue this route.

Pesticide technicians should know that any person who transports hazardous wastes must hold a valid registration issued by DTSC. Further, it is unlawful for any person to transfer custody of toxic waste to a transporter who does hold a valid registration. If in doubt, there is a list of registered hazardous waste transporters on the DTSC website.

PROPER DISPOSAL OF HAZARDOUS WASTES

This section should be entitled "How to avoid having to dispose of hazardous wastes". As mentioned in the previous section, the actual disposal of hazardous wastes is in the most part handled by commercial firms that specialize in this area. Recall also that agencies that generate less than a threshold amount of hazardous waste in a month are exempt from many of the management requirements.

Here are some practices used by many California mosquito and vector control agencies to minimize the amount of hazardous waste that requires special handling and management:

- Keep the use of pesticides that qualify as hazardous waste to a minimum.
- Avoid the use of pesticides that are on the Acutely Toxic Hazardous Waste list of EPA. Nearly all of these products are no longer available for use in California anyway.
- As much as possible, completely empty sprayer tanks of pesticide during applications. Avoid coming back from a job with partially-filled tanks.
- Do not collect rinse water from pesticide equipment cleaning in tanks for long-term storage, but use the rinse water for diluting water-**soluble** pesticides in spray tanks. This can only be done if the pesticide sprayed in the equipment that was cleaned is compatible with the pesticide to be **diluted** with the rinse water.
- Take advantage of recycling programs for empty pesticide containers offered by many pesticide distributors.
- Do periodic inventories of pesticides on-hand, and get rid of outdated or suspended materials. If you have materials that are legal, but no longer used in your program, sell or give them to other agencies that can use them.
- Constantly check for leaking containers. Either get rid of these materials, or transfer them to new containers.

Table 10.2. Pesticides listed as Toxic Hazardous Waste.

Chemical Name	Type of Pesticide	Trade Name
Amitrole	Herbicide	Several names
Cacodylic acid	Herbicide	Several names
Chlorobenzilate	Miticide	Acaraben®
Chlordane	Insecticide	Chlordane
Diallate	Herbicide	Abadex®
DBCP	Nematicide (fumigant)	Nemaset®, Nemafume®
1,2-D	Nematicide (fumigant)	DD, others
1,3-D	Nematicide (fumigant)	Telone®, Vortex®
2,4-D	Herbicide	Several names
DDT	Insecticide, rodenticide	DDT
Ethylene dibromide	Insecticide, nematicide	EDB®, Soilbrom®, others
Lindane	Insecticide	Isotox®, others
Maleic hydrazide	Plant growth regulator	MH-30®, others
Methyl bromide	Insecticide (fumigant)	Several names
Methoxychlor	Insecticide	Marlate®
Pronamide	Herbicide	Kerb®
Thiram	Antimicrobial, fungicide	Several names
Warfarin (0.3% or less)	Rodenticide	Several names
Zinc phoshide (10% or less)	Rodenticide	Several names

Table 10.3. Pesticides listed as Acutely Toxic Hazardous Waste.

Chemical Name	Type of Pesticide	Trade Name
Aldicarb	Insecticide	Temik®
Aldrin	Insecticide	Aldrex®, others
Aluminum phosphide	Insecticide (fumigant)	Phostoxin®
Aminopyridine	Bird repellent	Avitro®
Dimethoate	Insecticide	Roxion®, Cygone®, others
Dinoseb	Herbicide (desiccant)	Dinitro®, others
Disulfoton	Insecticide, acaracide	Di-Syston®
Endosulfan	Insecticide, miticide	Thiodan®, Phaser®
Endothrall	Herbicide	Accelerate®, Aquatholt®, others
Ethyl parathion	Insecticide	Parathion
Famphur	Insecticide (systemic)	Warbex®, Cyflee®
Heptachlor	Insecticide	Heptachlor
Methomyl	Insecticide	Lannate®
Methyl parathion	Insecticide	Penncap M®, others
Phorate	Insecticide (systemic)	Thimet®
Toxaphene	Insecticide	Strobane-T®, Toxakil®, others
Warfarin (more than 0.3%)	Rodenticide	Several names
Zinc phorphate (more than10%)	Rodenticide	Several names

Note: Data for Tables 10.2 and 10.3 from University of Florida IFAS Extension Document PI-18, Proper Disposal of Pesticide Waste, November 2005.

Chapter 11

THE FUTURE OF PESTICIDES IN PUBLIC HEALTH PROGRAMS

The history of **pesticide** use in public health programs, especially in connection with mosquito abatement in the California and elsewhere in the USA, has seen a continual series of changes over the past century or more. Public health pesticides have been controversial since their first use, and remain so to this day. Attitudes concerning pesticide use range from those who continue to lament the **suspension** of the use of DDT and other **persistent** conventional pesticides to those who believe *all* pesticide use should be discontinued. As with all contentious public policy issues, neither side has achieved a total victory, and probably neither ever will. One result of this continuing struggle is an arsenal of pesticides that, although much smaller than in previous years, is safer and less disruptive to the environment than ever before. To this situation should be added an ever-improving pesticide application technology, better methods for surveillance of both vector-borne diseases and vector **infestations**, and much better training of pesticide **applicators.**

It is unlikely that effective control of public health pests can ever be achieved based entirely on non-pesticide methods. Pesticides remain useful and necessary tools, widely available and frequently used by almost everyone. They influence our daily lives in dozens of positive ways: they increase our ability to produce food; they help protect us from diseases like malaria and plague; and they help make our general environment a more pleasant place in which to live. However, pesticides are not without disadvantages. They are expensive, they may themselves create human health problems, they may damage pets and wildlife in some instances, they may actually increase our pest problems by suppressing beneficial insects, and they may damage valuable agricultural crops. Pesticide applicators should continually be aware of the **hazards** associated with pesticide use, even though **products** used today in public health programs are far less hazardous than was the case 20-30 years ago.

When one considers pesticides as tools to be used in vector control operations, and not as the sole methods available, efforts to promote development and use of alternative tools become fully supportable. Some of these alternatives include **biological control**, habitat modification, genetic alteration of vector populations, and selective application of vector control operations. An example of selective application might be the ignoring of populations of potential vector mosquitoes in remote areas of the state where the chance of contact of people with the vectors is very low. In this case, it is more efficient for hardy backwoodsmen to rely on protective clothing and repellents to avoid mosquito bites.

Several vector control specialists have advocated the use of the term **Integrated Vector Management**, or IVM, to represent the preferred modern approach to vector control and to mirror the modern approach to management of agricultural pests called **Integrated Pest Management**, or IPM. What you call the modern approach is far less important than an appreciation of the principles involved. There are few differences in the principles of IVM and IPM.

A complete discussion of alternative methods of control of public health pests is beyond the scope of this manual. However, some understanding of these methods by pesticide applicators is important in making decisions about the materials and methods to be used in planning pesticide applications.

BIORATIONAL PESTICICIDES

Strictly speaking, the use of **biorational pesticides** is not an alternative to pesticide use. However, they are an alternative to the use of conventional pesticides such as **organophosphates**, **carbamates**, and pyrethroids. There are several definitions of biorational pesticides in current use. The general definition includes any pesticide of natural origin that has limited or no adverse effects on beneficial **organisms** or other components of the environment. This definition lacks precision, would exclude synthetic materials such as methoprene, and would have to acknowledge that pests are a component of the environment. **EPA** defines **biopesticides** (practically synonymous with biorational pesticides) as pesticides derived from natural materials as animals, plants, **bacteria**, and certain minerals. EPA places biopesticides into three categories: (1) **microbial pesticides**, (2) plant incorporated-**protectants**, and (3) **biochemical** pesticides. It is important to note that EPA recognizes problems with a definition for biorational pesticides, and has appointed a committee to deal with the issue. Also, they would regard synthetic materials such as methoprene a biorational pesticide because it acts in the same manner as a naturally-occurring hormone of insects.

Biorational pesticides are subject to the registration provisions of **FIFRA**. Classical biological **controls** (see below), including parasites and **predators**, are not subject to FIFRA regulation. Two examples of biorational pesticides are the microbial pesticide Bti (B*acillus thuringiensis israelensis*) and, as mentioned above, methoprene, a synthetic insect **growth regulator**.

CULTURAL PRACTICES

Many pest problems can be avoided by careful use of the proper cultural techniques. These are often highly specific techniques, such as dairy barn or chicken house sanitation methods, e.g., manure management to limit breeding sites for flies, etc. Specific information on cultural techniques of pest control should be obtained from your farm advisor or another knowledgeable source. Modern approaches to marsh management in coastal areas have advanced significantly over the past 20 years. The efforts to develop modern structures to impound runoff water from highways, and thus avoid pollution of adjacent streams and groundwater have been a very important development. The retention of these waters may however create breeding habitat for vectors.

BIOLOGICAL CONTROL

Biological control (BC) is the use of colonized or naturally occurring parasites or predators to control pest populations. Naturally occurring parasites or predators are called **natural enemies**. If the definition of BC is expanded to include microorganisms for this purpose, then pesticides such as Bti would qualify as both a BC agent and a biorational pesticide.

The development of biological control methods for control of public health vectors has long been a goal in California. Although some parasites and predators have shown promise in limited field trials, not all have been found to be practical for large-scale operations. On exception to this is the use of the mosquitofish (*Gambusia affinnis*). Many mosquito abatement programs in California have developed a program for rearing and distributing the fish as a **supplement** to conventional pesticide operations. These fish are particularly effective in degraded aquatic habitats such as poorly maintained swimming pools and fish ponds. Some larger mosquito and vector control programs in the state have large programs for development and implementation of biological control agents. As mentioned above, in contrast to biorational pesticides, which are subject to the registration provisions of FIFRA, biological control agents are not. However, the use of biological control agents may come under restrictions of agencies such as the California Department of Fish and Game.

ATTRACTANTS AND REPELLENTS

Attractants and repellents offer promise of helping control pests. In some cases chemicals may be used effectively to attract agricultural pests to traps, then expose them to lethal **doses** of a pesticide. Traps to control stinging Hymenoptera such as wasps have been used successfully in certain situations. However, traps designed to attract mosquitoes and other flying Diptera into backyards and similar settings have not shown impressive results. The published results of numerous controlled studies have shown that although impressive numbers of flying insects can be found dead in such traps, they have little impact on numbers remaining to bite or otherwise annoy people. Such traps have been used effectively as a surveillance tool.

Repellents that can be applied to the skin or clothing of people, pets, or other domestic animals are a useful alternative to pesticides, if used properly. The most successful skin repellents have been those containing DEET, a chemical developed by the US Department of Agriculture more than 50 years ago. Recently, other chemicals have been developed as skin repellents that appear to act with equal effectiveness.

Although not a repellent, affective methods to keep insect pests from being a nuisance is the use of insecticidal bed nets, door curtains, and window curtains. These methods have shown great promise in tropical areas of the world where malaria is a serious problem.

GENETIC CONTROL

In a few spectacular cases, massive populations of pest species have been managed and even locally eradicated through the use of genetic techniques. The most well known example of this kind of pest control involved the eradication of the screw-worm fly from the USA. A similar technique has recently been repeatedly employed in California to eradicate local infestations of Mediterranean fruit fly. To date, genetic control has not been used successfully in California against vector species. The concept of altering the genetic makeup of vectors to reduce their population sizes or change their ability to transmit **pathogenic** microorganisms is currently an area of intense research. Significant progress has been made in development of our understanding of the genetic makeup of vectors, and methods of altering this makeup. Successful large-scale programs based on these approaches are still in the future, but they hold an important promise for things to come.

GLOSSARY

Many of the words defined here have additional meanings. The definitions given here are related to pests, pesticides, and pest management.

A

Absorption — Movement of a chemical into a plant, animal, or the soil. Plants absorb substances through leaves, stems, or roots, animals absorb substances through skin breathing organs, stomach, mouth or intestines. Compare to *adsorption.*

Acaricide — A pesticide used to control mites and ticks. The term refers to Acarina (or Acari), the taxonomic group which mites and ticks belong.

Active ingredient — The component of a pesticide formulation that kills or controls pests. In other words, the chemical that is responsible for the toxic effect in a formulation.

Acute — In regard to pesticides, refers to effects from one exposure or exposure for a short period.

Acute dermal toxicity— The toxicity of a single dose (or short exposure) of a pesticide when absorbed through the skin.

Acute inhalation toxicity — The toxicity of a single dose (or short exposure) of a pesticide when inhaled into the lungs.

Acute oral toxicity— The toxicity of a single dose (or short exposure) of a pesticide when taken by mouth (eaten, swallowed, licked, etc.).

Additive — Any substance added to a pesticide to improve its performance. Same as *adjuvant.*

Adjuvant — An ingredient added to a pesticide to modify or enhance the effectiveness of the active ingredient

Adsorption — The process by which a substance is held (bound) to the surface of a soil particle or mineral in such a way that the substance is available only slowly. Clay and highly organic soils have a tendency to adsorb pesticides. Compare to *absorption.*

Adult — A full-grown, sexually mature insect, mite or other animal or plant.

Aerosol — A low-concentrate solution of a pesticide or combination of pesticides, usually in an oil solution formulated especially for use in aerosol generators.

Agitator — A paddle (or other mechanical device), air, or hydraulic action used to keep a pesticide formulation mixed in the tank.

Air blast — A type of pesticide sprayer that can deliver high and low volumes of spray; used for orchards, shade trees, sprayer vegetables, and fly control.

Annual — A plant that grows from a seed, produces flowers, fruit or seed the same year, and then dies.

Anticoagulant — A chemical that interferes with the normal clotting of blood. Some rodenticides are based on this principle.

Antidote — A medicine or other remedy for counteracting the effect of a poison. Antidotes are effective in reversing effects caused by certain pesticides, if administered promptly.

Applicator — A person or piece of equipment which applies pesticides.

Aquatic weeds — Plants or weeds that grow in water. The plants may float on the surface, grow up from plants or the bottom of the body of water (emergent), or grow under the surface of the water (submergent).

Artificial respiration — A form of first aid given to a person who has stopped breathing in order to get the person breathing again.

Atomize — To break up a liquid into very fine droplets by forcing it through a nozzle-like device having a very small opening.

Attractants — Substances or devices that attract insects or other pests to areas where they can be trapped or killed.

Avicide — A pesticide used to control birds.

B

Bacteria — Single-celled microorganisms (germs), some of which cause diseases in plants or animals. They cannot be seen without a microscope. (Singular: bacterium)

Bait — A food or other material that will attract a pest to a pesticide or to a trap where it will be trapped or killed. Baits can be mixed with pesticides in certain situations.

Bait shyness — The tendency for rodents, birds, or other pests to avoid a poisoned bait.

Biennial plant — A plant with a 2-year life cycle. It produces leaves and stores food in the first year, then produces fruits and seeds in the second year. After the second year the plant dies.

Biochemical — Having to do with the chemistry of living things.

Biological control (BC) — The use of colonized or naturally occurring parasites or predators to control pest populations. Some would expand the definition to include pathogenic microorganisms, since they are also parasites.

Biopesticides — See biorational pesticides

Biorational pesticides — Pesticides derived from natural materials as animals, plants, bacteria, and certain minerals. EPA recognizes three categories of biorational pesticides: (1) microbial pesticides, (2) plant incorporated-protectants, and (3) biochemical pesticides. Biorational pesticides are subject to FIFRA regulation. Most biological control agents are not.

Boom — A section of pipe (or tubing) to which pesticide sprayer nozzles can be attached to increase the area that can be treated by a pesticide in a single pass of a vehicle.

Botanical pesticides – Pesticides made from plants. Examples: nicotine, pyrethrum, rotenone and strychnine.

Broadcast application — A uniform application over an entire area.

Broadleaf plants — Plants having wide, rounded, or flattened leaves and netted veins. Examples: dandelions and roses. Compare to *Narrow leaf plants.*

Broad spectrum pesticide — A pesticide that is toxic to a wide range of pests. Same as *Non-selective.*

Buildup — Accumulation of a pesticide in soil, animals, or in the food chain.

C

Calibration — The measurement and adjustment of pesticide application equipment to apply a pesticide formulation at a desired application rate.

Canister — A metal or plastic container filled with absorbent materials that filter fumes and vapors from the air before they are inhaled by an applicator.

Carbamate — A synthetic organic pesticide that belong to a group of chemicals that are salts or esters of carbonic acid. Carbamates are used as fungicides, herbicides, and insecticides. Examples: aldicarb, carbaryl, carbofuran, and methomyl.

Carcinogen — A substance or agent capable of producing cancers.

Carcinogenicity — The capability of a substance to cause cancers.

Carrier — An adjuvant which is added to (or which dilutes) the active ingredient so that the formulation becomes easier to apply. Petroleum solvents and talc are examples. Also, the material that carries the pesticide to target. Water in a hydraulic sprayer or air in a mist blower are examples of this.

Cartridge — The part of the respirator that absorbs fumes and vapors from the air before the applicator inhales them.

Caution – The signal word used on pesticide labels to indicate a Toxicity Category III product.

Certified applicator— An individual who is certified to use or supervise the use of a restricted pesticide.

Cholinesterase – An enzyme found in the bodies of animals that controls nerve impulses. It is necessary for proper nerve function. Its activity can be affected in insects and warm-blooded animals (including people) by organophosphates and carbamates.

Compatibility — The degree to which two or more pesticides can be combined without significant reduction in effectiveness or safety.

Complete metamorphosis — The process of insect development which includes the egg, larva, pupa, and adult stages.

Controls — Experimental subjects not treated with a test chemical. An experiment that does not use controls is called "uncontrolled" and the results derived are usually not taken seriously by others.

Corrosive poison — A type of poison that contains a strong acid or base which will severely burn the skin, mouth, stomach, or other organs.

Cross contamination — When one pesticide gets into or mixes with another pesticide accidentally. This usually occurs in a previously-used pesticide container or in a poorly cleaned sprayer.

D

Danger – The signal word used on pesticide labels to indicate a highly toxic pesticide (Toxicity Category I). This signal word may be accompanied by the word *Poison* and the skull and crossbones symbol.

Decontaminate — To make safe, purify, make fit for use again by removing any pesticide from equipment or other surfaces as directed by a pesticide label, an agricultural authority, or the manufacturer of the pesticide.

Defoliant — A pesticide which causes the leaves of a plant to drop off.

Degradation — The breakdown of a more complex chemical into a less complex form. This process can be a result of the action of microbes, water, air, sunlight, or other agents.

Delayed action — The lack of an immediate response by a plant to an application of an herbicide. With some herbicides a delayed response is expected and it may take a while for maximum effects to be observed. Usually treated plants stop developing soon after treatment and then gradually die.

Deposit — The amount of pesticide remaining on the target immediately following an application. Compare to *Residue.*

Dermal — Through or by the skin; of or pertaining to the skin.

Dermal toxicity — The toxicity of a pesticide when it comes in contact with and absorbed through the skin. Dermal toxicity is the greatest hazard to people handling pesticides.

Desiccant — A pesticide used to draw moisture from or dry up a plant, plant part, or insect. Desiccants are used primarily for pre-harvest drying of actively growing plant tissues when seed or other plant parts are developed but only partially mature; or for drying of plants which normally do not shed their leaves, such as rice, corn, small grains, and cereals.

Diluent — Material, usually oil or water, mixed with a concentrate to dilute it to field strength.

Dilute — (verb) To make a pesticide less concentrated by adding water, oil, or other liquid or solid.

Dose (dosage) — The application rate of a pesticide, usually expressed in units of weight per unit of area, such as pounds per acre. Also, a measure used in testing to determine acute and chronic toxicities. In this case, usually expressed in units of weight of a chemical per unit of weight of a test animal or human, such as milligrams per kilogram (mg/kg).

Drift — The movement of pesticide droplets or particles by wind and air currents from the target area to an area not intended to be treated.

Dust (D) — A finely ground dry mixture combining a small amount of pesticide with an inert carrier such as clay, talc, or volcanic ash.

E

Ecology — The study of the relationship between a plant or animal and its surroundings.

Effective Dose (ED) — The ED_{50} is the dose that is effective in killing or otherwise affecting 50 percent of the tested subjects.

Emulsifiable concentrate (EC or E) – An oil solution containing a high concentration of active ingredient and an emulsifying agent. The emulsifying agent aids in mixing the concentrate with water to produce an emulsion for spraying.

Emulsifier — A chemical that helps one liquid form tiny droplets and thus remain (emulsifying suspended in another liquid.

Emulsion — A mixture in which one liquid is suspended (mixed up) as tiny droplets in another liquid. Example: oil in water.

Encapsulation — A method of formulating pesticides, in which the active ingredient is encased in a material (often plastic), resulting in sustained pesticidal release and decreased hazard. Also, a method of disposal of pesticides and pesticide containers by sealing them in sturdy, waterproof, chemical-proof containers which are then sealed in thick plastic, steel, or concrete to resist damage of breakage so the contents cannot escape to the environment.

EPA — The US Environmental Protection Agency, the federal agency responsible for the protection of the environment in the United States.

Epidemiological — Having to do with the study of the incidence and distribution of diseases in the broad sense (to include infectious diseases, metabolic disorders, poisonings, genetic defects, allergies, etc.).

Evaporate — To form a gas and disappear into the air; to vaporize.

Exemption — An exception to a policy, rule, regulation, law, or standard.

Exoskeleton — The segmented external skeleton of an arthropod.

Exposure — Contact with a pesticide through skin (dermal), mouth (oral), lungs (inhalation/respiratory), or eyes.

F

Face shield — A transparent piece of protective equipment used by a pesticide applicator to protect the face from exposure.

FDA – The US Food and Drug Administration, the federal agency that monitors pesticide residues on food products.

FIFRA — The Federal Insecticide, Fungicide, and Rodenticide Act, the federal law pertaining to pesticide regulation and use in the USA. The original act was enacted in 1947. It has been amended many times since then.

First aid — The first effort to help a victim while medical help in on the way.

Flowable (F) — Very finely ground solid material which is suspended in a liquid; usually contains a high concentration or large amount of the active ingredient and must be mixed with water when applied.

Fogger — An aerosol generator; a type of pesticide spray equipment that breaks pesticides into very fine droplets (aerosols or smokes) and blows or drifts the "fog" onto the target area.

Foliage — The leaves, needles, stems, and blades of plants and grasses.

Foliar application — Spraying a pesticide onto the stems, leaves, needles, and blades of grasses, plants, shrubs, or trees.

.**Formulation —** The resulting mixture of pesticide active ingredients, diluents, synergists, additives, and carriers. This is the form that pesticides are sold by distributors or retailers. It is also the form of pesticides that EPA registers.

Fume — A smoke, vapor, or gas.

Fumigant — A pesticide that enters the pest in the form of a gas and kills it. The fumigant may be a liquid that changes to a gas when it is applied. Methyl bromide, phostoxin, chloropicrin, and carbon bisulfide are examples.

Fungi — Groups of small plant organisms (often microscopic) which cause rots, molds, and plant diseases. Fungi grow from seed-like spores and produce tiny thread-like growths. Molds, mushrooms, and yeasts are examples. (Singular: fungus).

Fungicide — A pesticide used to control fungi.

G

Gas mask — A type of respirator which covers the entire face and protects the eyes as well as the nose and mouth. It filters and cleans the air better than cartridge respirators and is less likely to leak around the edges. This device is effective against air which contains sprays, dusts, or gases. (Note: A simple respirator will protect against a spray or dust without covering the eyes, but not against poisonous gases.)

Gram — A metric weight measurement equal to 1/l,000th of a kilogram; approximately 28.5 grams equal one ounce.

Granular pesticide (G) – A pesticide in the form of pellets, all of which are larger than dust particles. A granular formulation is dry and ready-to-use, and is made of small amount of pesticide and an inert carrier; the active ingredient is mixed with, absorbed, adsorbed, or pressed on or into the inert carrier.

Growth regulator — A pesticide that interferes with the normal growth or reproduction of a plant or animal. Growth regulators are considered biorational pesticides.

H

Hazard — A danger or risk of injury or other harm faced in connection with exposure to a pesticide. The degree of hazard is a result of a combination of toxicity and exposure.

Hectare — A metric area measurement equal to 10,000 square meters or approximately 2.47 acres.

Herbicide — A pesticide used to control plants, especially weeds.

High pressure sprayer — Same as *Hydraulic sprayer.*

Hormones — Chemicals naturally present in plants or animals that control growth or other physiological processes. Hormone-like chemicals can be synthesized to regulate plant and animal growth. They can also be used as pesticides through disruption of growth processes. Both naturally-occurring and synthesized chemicals that are used as pesticides are considered biorational.

Host — A living plant or animal that a pest depends on for survival.

Hydraulic sprayer — A machine that delivers large volumes of pesticide spray at high pressures (up to several hundred pounds per square inch) to the target. Hydraulic sprayers are used primarily for fruit trees, shade trees, and ornamentals. Same as *High pressure sprayer.*

Hydrocarbon — A chemical whose molecules consist entirely of carbon and hydrogen atoms. Crude oil is a mixture largely of hydrocarbons. Methane (natural gas) is the simplest hydrocarbon, with each molecule containing one atom of carbon and four atoms of hydrogen.

Hydrogen ion — A general term for all ions of hydrogen and its isotopes. The concentration of hydrogen ions in a solution is a measure of acidity or alkalinity, and is expressed in terms of the pH of the solution. See *pH.*

I

IGR — Insect growth regulator.

Impermeable — Characteristic of a living or non-living structure that cannot be penetrated by gases or liquids. The term is often applied to membranes of various types. A semipermeable membrane would be one that is only partially permeable, and some substances can pass through but others cannot.

Inactive — Status of a substance that does not react chemically with any other substance.

Incompatible — Refers to two or more pesticides that cannot be mixed together without a loss of effectiveness of one or both of the pesticides. Incompatible pesticides also my cause unintended injury to plants or animals.

Infestation —Pests that are found in an area or location where they are not wanted.

Ingest —To eat, drink, and swallow a substance.

Inhalation —The process of taking air into the lungs; breathing in.

Inhalation toxicity — The toxicity of a pesticide when breathed in through the lungs.

Inhibitor —A pesticide used to prevent or suppress growth or other physiological processes in plants. Also called a "growth inhibitor". See *Growth regulator.*

Inject **—**To force a pesticide into a plant, animal, building, other structure, or the soil.

Inorganic pesticides — Pesticides which do not contain carbon. Examples: Bordeaux mixture, copper sulfate, sodium arsenite, sulfuric acid, and salt.

Insect —A small invertebrate animal with three body regions and six jointed legs; may have two, four, or no wings.

Insecticide —A pesticide used to control insects.

Integrated pest management (IPM) — The management of pest problems using a combination of ecologically-sound approaches.

Interval — The time between two pesticide applications. Also, the time period between the final pesticide application and harvest.

Invertebrate — The very large group of animals that lack backbones. Insects, jellyfish, starfish, shellfish, squid, and spiders are examples.

IR-4 – Acronym for USDA Interregional Program 4, a program for the cooperative registration of minor uses of pesticides.

K

Kg — Kilogram. A metric weight measurement equal to 1,000 grams or approximately 2.2 pounds.

L

Label — Technical information about a pesticide in the form of printed material attached to or printed on the pesticide container.

Labeling — Technical information about the pesticide in the form of printed material provided by the manufacturer or its agent, including the label, flyers, handouts, leaflets, and brochures.

Larvae — Immature forms of invertebrate organisms. In insects, the forms that appear after hatching from eggs and before becoming a pupae.

Larvicide — A pesticide used to kill larvae, usually of insects.

LC_{50} The median lethal concentration of an active ingredient of a pesticide, i.e., the concentration of an active ingredient at which 50% of a group of test animals will die. LC_{50} is usually used to describe toxicity of pesticides in the air as gasses, dusts, or mists. LC_{50} is ordinarily expressed as parts per million (ppm) when the material is a gas, and micrograms per liter (mg/l) when a dust or mist. It is often used as the measure of *Acute inhalation toxicity.* As with all such indicators of toxicity, the lower the value, the more poisonous the pesticide.

LD_{50} The median lethal dose of an active ingredient of a pesticide, i.e., the dose of an active ingredient at which 50% of a group of test animals will die. LD_{50} is usually used to describe toxicity of pesticides in liquid form. Toxicity generally is expressed in milligrams of pesticide per kilogram of body weight (mg/kg). It is often used to measure *Acute oral toxicity* or *Acute dermal toxicity.* As with all such indicators of toxicity, the lower the value, the more poisonous the pesticide.

Leaching — The movement of a substance downward or out of the soil as the result of water movement.

Legal residue — A residue on a food crop for which a pesticide tolerance has been established and that is less than the permitted level.

Lethal — Causing or capable of causing death.

Life cycle — The procession of stages in the life development of an organism.

Liter — A metric measurement of volume equal to one cubic decimeter or, when dealing with liquid measurement, a little more than one quart.

Low concentrate solution (S) — A solution that contains a low concentration of active ingredient in a highly refined oil. These solutions are usually purchased as stock sprays and space prays and for use in aerosol generators.

Low pressure boom sprayer — A machine that delivers low to moderate volumes of pesticide at pressures of 30–60 psi. These sprayers most often are used for field and forage crops, pastures, and rights-of-way. Compare to *hydraulic sprayer.*

Low volume air sprayer — A machine similar to an *Air blast sprayer,* but with somewhat lower water volume and higher air velocity. This combination produces extremely fine droplets. Same as *Mist blower.*

Low volume spray — A spray application of 5–20 gallons per acre.

M

Mammals — Warm-blooded animals that nourish their young with milk and have skin that is more or less covered with hair.

Mechanical agitation — The stirring, paddling, or swirling action of a device which keeps a pesticide and any additives mixed in a spray tank.

Metabolism — The sum of the physical and biological processes in an organism by which chemicals are usually converted to energy and heat.

Metamorphosis — Changes in the shape, form, structure, and size of insects during their life cycle.

Metric — A system of measurement used by most of the world. The USA is one of the few nations in the world not to have adopted the metric system completely. Meters, grams, and liters are examples of metric units of measure.

Milligram (mg). A metric weight measurement equal to 1/1,000th of a gram; approximately 28,500 mg equal one ounce.

Milligrams per kilogram (mg/kg) — A measurement used to express the number of kg of a pesticide per kg of body weight of a test animal that will produce some kind of effect. The effect can be a sign of irritation, evidence of illness, or death.

Microbial pesticide — A pesticide consisting of microorganisms or their by-products. *Bacillus thuringiensis israelensis* (Bti) is an example, and is considered a biorational pesticide.

Microgram — A metric weight measurement equal to 1 millionth of a gram. Approximately 28,500,000 micrograms equal one ounce.

Mist blower — Same as *low volume air sprayer.*

Mites — Tiny animals closely related to ticks. A mite has six legs during the larval and nymphal stages, but eight legs as adults.

Miticide — A pesticide used to control mites. A miticide is a type of acaricide.

Mode of action — The manner in which a pesticide affects pests, as well as non-target organisms, including people, pets, and other desirable animals.

MPH — Miles per hour.

MTD — Maximum tolerated dose, the highest dose of a chemical that does not alter the life span or severely affect the health of an animal.

Mutagenicity — The ability of a substance to induce a mutation.

Mutation — A change in a gene that is passed from one generation to the next. Such a change may result in a significant change in an organism, or no observable change at all.

N

Natural enemies — Naturally occurring predators and parasites in the environment that attack pests.

Nematicide — A pesticide used to control nematodes. Nematicides are often applied as a soil fumigants to control nematodes infesting roots of crop plants.

Nematode — A worm-like invertebrate organism that feeds on or in plants and animals. Nematodes have many common names, including roundworms, threadworms, and eelworms. Some are microscope, some are visible to the naked eye, and many kinds are internal parasites of people and other animals.

Neoprene — A synthetic rubber often used to make gloves and boots that offer skin protection against most pesticides.

Neurotoxicity — The poisonous effect of pesticide on nerve tissue.

Nitrophenol — A synthetic organic pesticide that contains carbon, hydrogen, nitrogen, and oxygen.

NOEL — No observable effect level; the dose of a chemical that produces no observable effects when given to animals for long periods of time.

Non-persistent — A pesticide that breaks down almost immediately, or only lasts for a few weeks or less on a treated area. The pesticide may break down by exposure to light, moisture, or microorganisms; or it may evaporate. In some situations, non-toxic break-down products may remain.

Non-selective pesticide — A pesticide that is toxic to a wide range of pests, or toxic to more than one animal or plant. Same as *Broad spectrum.*

Non-target — Any plant, animal, or other organism that is not the planned object of a pesticide application.

Nozzles — Devices that determine the flow rate, droplet size, and discharge pattern of a pesticide application. Nozzles are mounted in various ways, usually at the ends of wands or along spray booms. Types of nozzles include flat fan, even flat fan, cone, flooding, atomizing, broadcast, and solid stream.

Nymph — The stage of development in certain insects after hatching when the young insect resembles the adult insect but is smaller. In flying insects, nymphs lack fully developed wings.

O

Oils — Liquids used to carry or dilute an active ingredient in a pesticide formulation. Certain oils may be used alone in aquatic habitats to control mosquito larvae.

Oncogen — A substance capable of inducing tumors. Same as *Carcinogen*.

Oral — Anything pertaining to the mouth. In pesticide usage, a route of entry of a pesticide when ingested.

Oral toxicity — The toxicity of a pesticide when ingested.

Organic pesticide – Pesticides that contain carbon. The two major types are petroleum oils and synthetic organic pesticides.

Organism — Any living thing.

Organochlorine — Same as *Chlorinated hydrocarbon.*

Organophosphate — A synthetic organic pesticide that contains carbon, hydrogen, and phosphorous. It acts by inhibiting the blood enzyme *cholinesterase*. As a rule, organophosphates are less persistent than organochlorine pesticides. Malathion and parathion are organophosphates.

Original container — The package prepared by the manufacturer in which the pesticide is placed and then sold. The package must have a label telling what the pesticide is, how to use it safely and correctly, and how to safely and legally dispose of the empty container.)

Ornamentals — Plants which are used to beautify homes, gardens, and lawns.

P

Parasite — An organism that lives on, and at the expense of another organism (called the host). The host may be harmed by the parasite, and if the host is a desirable plant or animal the parasite is also a pest. If the host is a pest, the parasite is a biological control agent.

Pathogen — A disease-producing microorganism.

Perennial — A plant that normally lives for more than two years. Shrubs and trees are perennials.

Persistent — A pesticide remains in the environment for a long time.

Pest — An undesirable organism for any one of a variety of reasons. Pests compete with people for food and fiber or attack people, pets, domestic animals, and desirable wildlife directly. Pests can be weeds, insects, rodents, birds, microbial organisms, snails, and many other organisms.

Pesticide — A chemical substance or other agent used to control, destroy, or prevent damage by or protect something from a pest.

Pesticide tolerance — The amount of pesticide residue that may legally remain on a food or feed. The EPA sets pesticide tolerances, and the FDA enforces them.

Petroleum oils — Pesticides refined from crude oil for use as pesticides.

pH — A measurement scale based on the hydrogen ion concentration of a solution used to express its acidity or alkalinity. Pure distilled water has a pH of 7 (=neutral), a solution with a pH less than 7 is acidic, a pH more than 7 is alkaline.

Pheromones — Chemicals produced by insects and other animals to communicate with other members of the same species, or synthetic chemicals that function as pheromones. Some are used as pesticides that act by confusing communication individuals. They are also used as attractants either in surveillance programs or in control programs.

Physiological — Having to do with the mechanisms of body function of organisms.

Phytotoxic — Harmful to plants.

Poison — A chemical or material that can cause injury or death when eaten, absorbed, or inhaled by plants or animals, including people.

Pollutant — A harmful chemical or waste material discharged into the water, soil, or atmosphere; an agent that makes something dirty or impure.

Pollute — To add an unwanted material (often a pesticide) to the environment in a way that degrades it.

Post-emergence — After a specified crop or weed has pushed up through the soil and become visible.

Post-emergent — A pesticide used to control a crop or weed after it has appeared.

Potency — The strength of something. The potency of a pesticide expresses how toxic it is.

Ppb — Parts per billion. Usually describes the amount of a chemical present in soil or water determined by modern analysis.

Ppm — Parts per million. Used in the same way as ppb, but expresses a lower concentration.

Predacide — A pesticide used to control vertebrate predators (usually coyotes).

Predator — An insect or other animal that attacks, feeds on, and destroys other insects or animals. When predators attack pests they are biological control agents. When coyotes attack sheep, they are pests.

Pre-emergence — Before a specified crop or weed has pushed up through the soil and become visible.

Pre-emergent — A pesticide used to control a crop or weed before it has appeared.

Pre-harvest — The time just prior to the picking, cutting, or digging up of a crop.

Pre-plant— The application of a pesticide before planting a crop.

Product — The pesticide as it is packaged and sold; it usually contains an active ingredient plus adjuvants It is

Propellent — A liquid under pressure in self-pressurized pesticides that forces the active ingredient from the container. Upon release into the atmosphere, propellents become gasses.

Properties — The characteristics of a pesticide.

Protectant — A pesticide that is applied before pests are actually found but where they are expected. Sometimes called a *preventative*.

Protective gear — Clothing, materials, or devices that offer protection from exposure of applicators to pesticides. Gloves, aprons, shoes, coveralls, hats, cartridges, respirators, and gas masks are all examples of protective gear.

Protopam chloride (2-PAM) — An antidote used for organophosphate poisoning, but not for carbamate poisoning.

Psi — Pounds per square inch. A measure of pressure.

Pupa — An insect form that occurs after the final larval stage and before appearance of the adult form in insects having complete metamorphosis (flies, beetles, butterflies and moths, wasps, etc.) Pupae are usually non-feeding, and sometimes immobile (mosquitoes are an exception).

Pyrethrin — The insecticidally-active chemical component of pyrethrum insecticides. Both the active ingredient and the insecticide are sometimes called pyrethrins. The correct usage would be to refer to the former as pyrethrin, the latter as pyrethrum.

Pyrethroids — Synthetic compounds produced for their chemical resemblance and insecticidal similarity to pyrethrin.

R

Rate — The amount of a pesticide (or pesticide formulation) that is delivered in a pesticide application. Rates are expressed in units of volume or weight per units of area or time (e.g., gallons per acre, pounds per acre, gallons per minute, etc.).

Recommendation — A suggestion from or advice given by a Farm Advisor, Extension Specialist, or other agricultural authority.

Repellent — A pesticide that makes pests leave or avoid a treated area, surface, animal, or plant.

Residual pesticide — A pesticide remaining in the environment for a long time. Some residual pesticides may continue to be effective for days, weeks, and months. The organochlorine dieldrin remained effective as a termite control agent for years.

Residue — The amount of pesticide that remains on or in a crop or animal or on a surface after it has been treated. Residues are usually measured in ppm. Compare to *Deposit.*

Resistant — Refers to an organism that is able to survive pesticide doses that are fatal to susceptible organisms of the same species..

Respirator — A face mask which filters out poisonous gases and particles from the air, enabling a person to breathe and work safely. Respirators are used to protect the nose, mouth, and lungs from pesticide poisoning.

Respiratory — Having to do with breathing and oxygen uptake.

Respiratory toxicity — The toxicity of a pesticide when inhaled.

Restricted use pesticide — A pesticide that has been classified by the EPA for use only by an appropriately certified applicator.

Reversible — A toxic effect that is temporary or curable.

Rhizome — A root-like underground stem.

Rodent — Any animal of the order Rodentia. Examples include mice, rats, squirrels, gophers, woodchucks.

Rodenticide — A pesticide used to control rodents.

Runoff — The sprayed liquid which does not remain on a plant or sprayed surface. See *Point of drip.*

S

Selective pesticide — A type of pesticide that is more toxic to some types of plants or animals than to others. An herbicide that kills crabgrass in a cornfield but does not injure the corn is an example of a selective pesticide.

Sensitive — Easily injured or affected by; susceptible to pesticidal effects at low dosage. Many broadleaved plants are sensitive to 2,4-D.

Sensitive areas — Locations where pesticide applications could cause great harm. Applications in sensitive areas should be done with extreme care and caution. Examples include streams, ponds, houses, barns, parks, etc.

Shock — The severe reaction of the human body to a serious injury. Shock can lead to death if not treated (even if the actual injury was not a fatal one).

Short-term pesticide.— A pesticide that breaks down quickly after application into non-toxic byproducts. Same as *Non-persistent.*

Signal words — Words which must appear on pesticide labels to indicate the toxicity class to which they belong. Allowable words are Caution, Warning, and Danger-Poison. The skull and cross bones symbol must appear with the signal words Danger-Poison.

Sign — Evidence of exposure to a dangerous pesticide or other disease process in a plant or animal that is observable by a person other than the plant or animal affected. In people, signs are observable by others even if the person affected is unconscious. In other animals and in plants, only signs are available as evidence of poisoning or illness. Compare to *Symptom.*

Silvicide — A pesticide used to control unwanted brush and trees.

Slurry — A thick suspension of a pesticide made from a wettable powder and water. See *Wettable powder.*

Soil fumigant — A pesticide in the form of a gas used to control pests in the soil. Some fumigants are in liquid form when applied, but become gasses in the soil. To lengthen the time of effectiveness, covers such as plastic sheets are sometimes used.

Soluble — A characteristic of a material capable of dissolving in a liquid.

Soluble powder (SP) — A dry preparation of finely-ground powder containing a relatively high concentration (15%–95%) of active ingredient that dissolves in water (or another liquid) and forms a solution so that it can be applied.

Solution — The mixture of a substance into another substance (usually a liquid) in which all ingredients are completely dissolved without their chemical characteristics changing. True solutions do not settle out or separate in normal use. Sugar mixed in water is an example of a solution.

Solvent — A liquid that will dissolve another substances to form a solution. When sugar is dissolved in water, the sugar is the solute, the water is the solvent.

Species — A group of populations of potentially interbreeding living organisms. Since passage of the endangered species act, the definition has been broadened to consider a population having some demonstrable stable difference from another population as a species in the legal sense, even if the populations are potentially interbreeding.

Spiders – Small to moderately large animals classified in the Class Arachnida. Spiders are closely related to mites and ticks, and along with insects are classified as arthropods.

Spillage — Any escape, leakage, dripping, or running over of a pesticide.

Spore — An inactive form of a micro-organism that is capable of becoming active again.

Spot treatment — A pesticide application directed at a small area, such as at specific plants. Opposite of general application. Spot treatments are commonly used in pest control operations in homes and other indoor situations.

Spreader — An adjuvant that increases the area that a given volume of liquid will cover on a solid surface (such as a leaf).

Stomach poison — A pesticide which kills an animal when ingested.

Structural pests — Any animal or organism that can damage houses, barns, and other structures. Examples are termites, carpenter ants, insects and rodents.

Summer annuals — Plants that germinate in the spring, do most of their growing in the summer, produce flowers or seeds, and then die in the fall.

Supplement — Any substance added to a pesticide to improve its performance. Same as *Adjuvant.*

Surface active agent — An adjuvant that reduces surface tension between two different substances (such as water agent and oil). (Note: Most *Adjuvants* may be considered surface active agents). Also known as a *Surfactant.*

Surface water — Water which is located above ground such as ponds, lakes, streams, and rivers.

Surfactant – Same as surface active agent. Surfactants improve the emulsifying, dispersing, spreading, and wetting properties of pesticides.

Susceptibility — The degree to which an organism can be injured or affected by a pesticide at a known dosage.

Susceptible species— A species of organisms that is capable of being injured, diseased, or poisoned by a pesticide; not immune.

Suspension — A pesticide formulation in which finely divided solid particles are mixed in a liquid.

Suspension of a pesticide registration — A preliminary assessment of the risks and benefits of a pesticide prior to cancellation. Suspensions occur when the EPA determines that an imminent hazard is posed by a pesticide. During the suspension process the pesticide in question may be marketed. If the EPA has determined that unreasonable risks would be posed by continued use of the pesticide during the hearing process, an *Emergency Suspension Order* may be issued. In this case, the pesticide may not be marketed during the hearing process. See also *Cancellation.*

Swath — The width of ground covered by a sprayer when it moves across a field or other treated area.

Symptom — A feeling of unhealthiness that can be expressed by a person. It may represent a warning of pesticide poisoning. Plants cannot display symptoms, and most animals cannot display them in a readily recognizable form. Reasonable people will disagree on the question of whether non-humans can show symptoms at all, and the word symptom is often misused for “sign”.

Synergistic — When the combined action of two or more pesticides is greater than the sum of their activity when used alone.

Synthetic organic pesticides — Man-made pesticides that contain carbon, hydrogen, and other elements.

T

Target pest — A population of pests at which a pesticide application or other control method is directed.

Toxic dose (TD) — The dose of a chemical that produces signs of toxicity.

Technical grade — A pesticide as it is manufactured by a chemical company before formulation. Commonly used in toxicology laboratories for tests of various kinds.

Thermal — Of, about, or related to heat.

Ticks – Small blood-sucking arthropods belonging to the Class Arachnida (spiders, ticks, and mites). They resemble some insects, to which they are related, but they have eight jointed legs, two body regions, no antennae (feelers), and no wings. As vectors of disease organisms, their importance is second only to mosquitoes.

Tolerance — The legal limit of the amount of pesticide that may remain in or on foods marketed in the USA. Tolerances are established by EPA, and enforced and monitored by FDA..

Toxic — Poisonous to plants and animals, including people.

Toxicant – A Poison; an agent capable of being toxic.

Toxicity — How poisonous a pesticide is to an organism; the innate ability of a pesticide to produce injury. *Test animals* are used to establish *dermal, inhalation*, and *oral* toxicities.

Toxin — A poison produced by a plant or animal.

Trade name — Same as *Brand name.*

Treated area — A house, barn, field, forest, garden, greenhouse, or other place where a pesticide application has been made.

Tumor — An unregulated growth of cells.

U

ULV — Ultra low volume. An application of a pesticide at a rate of less than ½ gallon per acre (5 liters per hectare). Because the volumes be sprayed are so small, extremely low doses of insecticide result, even when the pesticides are sprayed undiluted.

Uniform coverage — The even application of a pesticide over an entire area, plant, or animal.

Upwind — A relative location of a person with his or her back towards the direction of a prevailing wind. Also see *downwind.*

USDA – The US Department of Agriculture.

V

Vapor — Gas, steam, mist, fog, fume, or smoke.

Vaporize — To evaporate; to form a gas or other forms of vapor.

Vector — A vehicle for transporting a disease-producing organism (pathogen) from one host to another. In vector ecology, the most common vectors are insects and other arthropods. Vectors can transfer pathogens from one animal to another, and from one plant to another.

Vertebrate — An animal with a backbone (bony spinal column) Mammals, fish, birds, snakes, and frogs are vertebrates.

Virus — A microorganism that can grow and reproduce only in living cells of other organisms. Often, viruses cause diseases in their hosts and are then pathogens.

Volatility — How quickly and easily a liquid or solid evaporates at ordinary temperatures when exposed to the air.

W

Waiting period — Same as *Time interval.*

Warning – The signal word used on pesticide labels to designate a pesticide that is moderately toxic. (Toxicity Category II).

Weathering — The wearing away of pesticides from the surfaces they were applied to because of wind, rain, snow, ice, and heat.

Weed — A plant growing where it is not wanted.

Weed control — Eradication, inhibition, or limitation of weeds, weed growth, or weed infestations, actions taken to prevent weeds from interfering with crop profitability or the efficiency of other operations.

Wettable powder (WP or W) — A dry (powder) preparation that is mixed with water to form a suspension that is used for spraying. Unlike a *Soluble powder,* it does not dissolve in water. Suspensions must be added to tanks that have already been partially filled with water, and the mixture must be agitated in some way to avoid lumpy formulations that can clog nozzles and result in improper application.)

Winter annuals — Plants which germinate in the fall or winter, do most of their growing in the spring, produce flower and seeds, and then die by early summer.

APPENDIX 1

MEDICAL SUPERVISION (CHOLINESTERASE MONITORING)

California Health and Safety Code Section 6728

(a) Whenever an employee handles a pesticide in toxicity category one or two that contains an **organophosphate** or **carbamate**, for the purpose of producing an agricultural commodity, the employer shall maintain use records that identify the employee, name of the pesticide and the date.

(b) Each employer who has an employee that regularly handles pesticides specified in (a) shall have a written agreement signed by a physician, that includes the names and addresses of both the physician providing the medical supervision and the employer responsible for the employees, stating that the physician has agreed to provide medical supervision and that the physician possesses a copy of, and is aware of the contents of the document "Medical Supervision of Pesticide Workers-Guidelines for Physicians" (available from the Office of Environmental Health Hazard Assessment). A copy of this agreement shall be given to the commissioner by the employer no later than when an employee begins to regularly handle pesticides specified in (a).

(c) The employer's responsibilities for medical supervision for employees regularly handling pesticides specified in (a) shall include the following:

(1) All covered employees shall have baseline red cell and plasma **cholinesterase** determinations. Baseline values shall be verified every two years. For new employees, the medical supervisor may accept previously established baseline values if they are obtained in accordance with these regulations by the same laboratory methodology and are acceptable to the laboratory which will analyze the new employee's blood samples.

(2)(A) The employer shall ensure that each employee, not previously under medical supervision associated with that employer, has red cell and plasma cholinesterase determinations within three working days after the conclusion of each 30-day period in which pesticides specified in (a) are regularly handled.

(2)(B) After three tests at 30-day intervals, further periodic monitoring shall be at intervals specified in writing by the medical supervisor except for verification of baseline as specified in (1).

(2)(C) Where the medical supervisor has made no written recommendation for continued periodic monitoring, the testing **interval** shall be 60 days.

(3) The employer shall keep a record of the agreement to provide medical supervision, use records, all recommendations received from the medical supervisor and all results of cholinesterase tests required to be made on his employees by this section or by the medical supervisor. Records required by this section shall be maintained for three years and shall be available for inspection by the employee, the director, commissioner, county health official, or state health official.

(4) The employer shall follow the recommendations of the medical supervisor concerning matters of occupational health.

(5) The employer shall post the name, address, and telephone number of the medical supervisor in a prominent place at the locale where the employee usually starts the workday or, if there is no locale where the employee usually starts the

workday, at each worksite or in each work vehicle.

(d) The employer shall investigate the work practices of any employee whose red cell or plasma cholinesterase levels fall below 80% of the baseline. The investigation of work practices shall include a review of the safety equipment used and its condition; and the employee's work practices which included employee sanitation, pesticide handling procedures, and equipment usage. The employer shall maintain a written record of the findings, any changes in equipment or procedures and any recommendations made to the employee.

(e) The employer shall remove an employee from exposure to organophosphate or carbamate pesticides if the employee's plasma cholinesterase level falls to 60% or less of baseline, or if red cell cholinesterase falls to 70% or less of baseline. The employee shall be removed from further exposure until cholinesterase values return to 80% or more of their respective baseline values. The employer shall maintain written records of the dates of removal and the dates when employees are returned to exposure.

(f) To meet the requirements of these regulations, red cell and plasma cholinesterase tests ordered by a medical supervisor for occupational health surveillance shall be performed by a clinical laboratory currently approved by CDHS to perform these tests.

APPENDIX 2

REPORTING OF PESTICIDE SPILLS

California Health and Safety Code Section 105215

(a) Any public employee, as defined in Section 811.4 of the Government **Code**, whose responsibilities include matters relating to health and **safety**, protection of the environment, or the use or transportation of any pesticide and who knows, or has reasonable cause to believe, that a pesticide has been spilled or otherwise accidentally released, shall promptly notify the local health officer or the notification point specified in the local hazardous materials response plan, where the plan has been approved by the State Office of Emergency Services and is in operation. The operator of the notification point shall immediately notify the local health officer of the pesticide spill report.

(b) The local health officer shall immediately notify the county agricultural commissioner and, at his or her discretion, shall immediately notify the Director of Environmental Health Hazard Assessment of each report received. Within seven days after receipt of any report, the local health officer shall notify the Director of Pesticide Regulation, the Director of Environmental Health Hazard Assessment, and the Director of Industrial Relations, on a form prescribed by the Director of Environmental Health Hazard Assessment, of each case reported to him or her pursuant to this section.

(c) The Office of Environmental Health Hazard Assessment shall designate a phone number or numbers for use by local health officers in the immediate notification of the office of a pesticide spill report. The office shall from time to time establish criteria for use by the local health officers in determining whether the circumstances of a pesticide spill warrant the immediate notification of the office.

APPENDIX 3

CONVERSIONS OF UNITS AND FORMULAS USED WITH PESTICIDES

CONVERSIONS

Length

1 mile (mi) = 1.609 kilometer (km)
1 km = 0.621 mi
1 meter (m) = 1.094 yards
1 centimeter (cm) = 0.394 inches (in)
1 in = 25.4 mm
1 micron (mμ) = 0.001 mm
1 mμ = 1/25,000 in

Speeds

1 mile/hour (mph) = 1.609 kilometers/hour (km/h)
1 mph = 0.447 meters/second (mps)
1 km/hr = 0.621 mph

Area

1 acre (ac) = 0.405 **hectares** (ha)
1 ha = 2.471 ac
1 ac = 43,560 ft^2

Liquids

1 fluid ounce (fl oz) = 0.0296 liters (l)
1 pint (pt) = 0.473 l
1 pt = 16 fl oz
1 gallon (gal) = 3.785 l
1 gal = 128 fl oz
1 pound (lb) = 0.454 kilogram (kg)
1 liter (l) = 33.81 fl oz
1 l = 2.113 pt
1 l = 0.264 gallons (gal)

Weight

1 ounce (oz) = 0.0283 kg
1 kg = 2.205 lbs

APPLICATION RATES

1 oz/ac = 0.070 kg/ha
1 meter/sec = 2.24 mph
1 l/ha = 13.69 fl oz/ac
1 l/ha = 0.855 pts/ac
1 kg/ha = 0.898 lb/ac
1 kg/ha = 14.27 oz/ac

FORMULAS

Gallons per acre = (5,940 x gallons per minute/nozzle)/(mph x nozzle spacing)

Gallons per minute per nozzle = (gallons per acre x mph x nozzle spacing)/5,940

Ounces per minute per nozzle = (gallons per acre x mph x nozzle spacing x 32)/1,485

Mph = distance traveled (ft)/(88 x minutes)

Mph = distance traveled (ft)/(0.47 x seconds)

ADDITIONAL INFORMATION

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WEBSITES

California Department of Pesticide Regulation. http://www.cdpr.ca.gov/

California Department of Public Health, Vector-borne Disease Section http://www.cdph.ca.gov/programs/vbds/Pages/default.aspx

California Department of Toxic Substances Control Program (DTSP). A program of Cal/EPA http://www.dtsc.ca.gov/

California Environmental Protection Agency (CAL/EPA) http://www.calepa.ca.gov/

Colorado State University Extension – Agriculture. Sprayer Calibration Fundamentals. http://www.ext.colostate.edu/pubs/farmmgt/05003.html

Cooperative Extension Service, College of Tropical Agriculture, University of Hawaii at Manoa. Calibration of Pesticide Application Equipment. http://pestworld.stjohn.hawaii.edu/studypackets/calibrat.html

Tee-Jet®. Offers technical information of a variety of subjects related to calibration http://www.teejet.com/

United States Environmental Protection Agency pesticide website: http://www.epa.gov/pesticides

University of Illinois at Urbana-Champaign, U. Illinois Extension Pesticide Safety Education Program. An on-line serial publication devoted to pesticide safety issues. http://www.pesticidesafety.uiuc.edu/newsletter/html/200405c.html