CHAPTER 3:

PESTICIDE TYPES & FORMULATIONS

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I. Introduction

Chapter Objectives

By the time you finish this chapter, you will

- know the definition of a pesticide;
- know definitions and abbreviations for types of formulations;
- be familiar with the major families of pesticides and their modes of action;
- know what to consider in choosing the best formulation and when to use it;
- understand the dangers of various formulations and how to protect yourself.

Terms To Know

Abrasive — Capable of wearing away or grinding down another object.

Active Ingredient — Chemical that controls target pest and has toxicity.

Aerosol — Fine spray produced under pressurized gas that leaves small fine droplets of pesticide suspended in air.

Agitation — Process of stirring or mixing.

Alkaline — Opposite of acidic; having pH greater than 7.

Carrier — Primary material used allowing effective pesticide dispersal; for example, talc in dust formulations.

Compatibility — Ability of two compounds to mix without affecting each other's chemical properties.

Dilute — To make less concentrated.

Emulsion — Mixture of two or more liquids that are not soluble in one another; one is suspended as small droplets in the other.

Insoluble — Does not dissolve in liquid.

Nontarget — Any site or organism other than the site or pest toward which the control measures are being directed.

Pesticide handler — Person who directly works with pesticides, such as mixing, loading, transporting, storing, disposing, and applying, or working on pesticide equipment.

Petroleum-based — Made from petroleum products, such as xylene, refined oil, or kerosene.

Soluble — Able to dissolve in another substance, usually as a liquid.

Solution — A mixture of substance without chemical change taking place.

Solvent — Liquid, such as water, kerosene, xylene, or alcohol, that will dissolve pesticide (or other substance) to form solution.

Suspension — Substance that contains undissolved particles mixed throughout liquid.

Target pest — Pest toward which control measures are being directed.

ULV (ultra-low-volume) — Concentrations that approach 100% active ingredient.

Volatile — Evaporating rapidly; turning easily into a gas or vapor.

Many of us have used the word *pesticide*, but how often have we really thought about what it means? According to Federal law, as defined by the amended Insecticide, Fungicide and Rodenticide Act (FIFRA), a *pesticide* is any substance or mixture of substances intended for destroying, preventing or mitigating insects, rodents, nematodes, fungi or weeds, or any other form of life declared to be pests; and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.

Many new chemicals are being developed which do not fit our traditional views of what a pesticide is and how it should be applied. For example, are insect pheromones pesticides? What are plant growth regulators? Is dish detergent a pesticide when it is used to kill whiteflies?

Pesticides that target a particular group of organisms are given specific names to reflect their activity. The names are derived from the Latin or scientific name for the group (Table 3.1). The ending or suffix *-cide* means kill or killer. But not all pesticides end with *-cide*. Examples include: **growth regulators,** which stimulate or retard the growth of pests; **defoliants,** which cause plants to drop their leaves; **dessicants**, which speed the drying of plants for mechanical harvest or cause insects to dry out and die; **repellents** which repel pests; **attractants**, which attract pests, usually to a trap; and **chemosterilants**, which sterilize pests. **Pheromones**, are *scents* produced by animals to communicate to other members of the same species, they are used as attractants to monitor or trap insects. Finally, the term **biocide** is often referred to as a pesticide that kills a wide range of organisms and is toxic to both plants and animals.

Table 3.1. Major Pesticide Families

Pesticide Type	Used Against
Acaricide (miticide)	Mites
Algicide	Algae
Avicide	Birds (Aves)
Bactericide	Bacteria
Fungicide	Molds, mushrooms, fungal diseases (Fungi)
Herbicide	Weeds
Insecticide	Insects and related animals
Molluscicide	Snails and slugs (Mollusca)
Nematocide	Nematodes
Rodenticide	Rats, mice or other rodents

II. Pesticide Classification

Pesticides may be put into categories or "classified" in several ways. Originally classified according to the ways they entered the pest, pesticides are now also classified according to their chemical properties (Table 3.2).

Modes of Entry & Chemical Group

The ways pesticides come in contact with or enter the target are called *modes of entry*. These include contact, systemic, stomach poisons, fumigants, and repellants.

Contact pesticides must come into physical contact with the pest to be effective. Contact herbicides kill only the plant parts to which they are applied. For example, diquat bromide is a contact herbicide used to control broadleaf weeds. Contact insecticides may kill the insect when applied directly, or may kill when an insect contacts a residue on a surface.

Systemic pesticides are applied to either plants or soil and translocated or moved throughout plants. Systemic herbicides are taken up by the foliage or the roots and move throughout the target plant, and

Table 3.2: Common pesticide chemical groups.

CHEMICAL GROUP	EXAMPLE	MODE OF ACTION
INSECTICIDES		
Organochlorines	DDT, methoxychlor	Contact
Organophosphates	Malathion, ethyl-parathion, Diazinon	Contact/stomach poison
Carbamates	Methomyl (Lannate©), Carbaryl (Sevin©)	Contact/stomach poison
Botanicals	Nicotine, rotenone	Contact/stomach poison
Pyrethroids	Permethrin (Ambush©)	Contact
Fumigants	Methyl bromide	Fumigant
Insect growth regulators	Methoprene	Systemic
HERBICIDES		
Inorganics	Sodium chlorate	Contact
Organic arsenicals	MSMA, DSMA	Contact/systemic
Phenoxy	2, 4-D, MCAP, MCPP	Systemic
Amides	Pronamide (Kerb©), alachlor (Lasso©)	Contact/systemic
Dinittoanilines	Trifluralin (Treflan©), Oryzalin (Surflan©)	Contact
Triazines	Atrazine (AAtrex) Cyanazine (Bladex©) Simazine (Princep)	Systemic
FUNGICIDES		
Inorganics	Copper Sulfur	Contact
Triazines	Anilazine (Dyrene©)	Contact
Substituted aromatics	Chlorothalonil (Bravo©)	Contact

are commonly used to control established perennial weeds. Systemic insecticides (e.g., aldicarb) are applied to soil, move through the host plant, and are fed on by the target insect when it chews or sucks on the plant (Fig 3.1). If the insect does not feed on the plant, it will not be controlled.

Stomach poisons must be eaten to control the pest. Baits for insects, birds, and rodents contain toxins that must be taken internally.

Fumigants are poisons applied as liquids that turn to gas. Fumigants are used to remove stored product pests from fruits, vegetables and grains, and are used to control pests in soil.

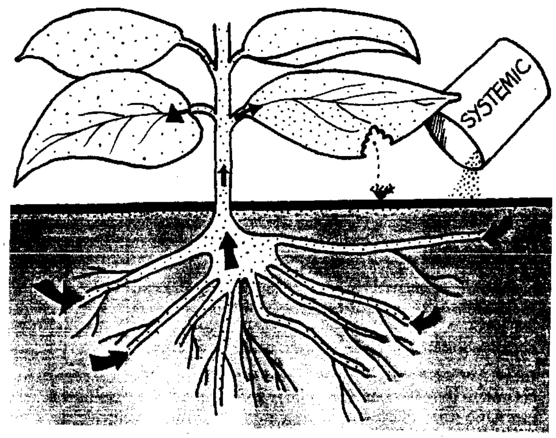

Figure 3.1 Systemic Pesticide

Repellents do not kill but are distasteful enough to keep pests away from treated areas/commodities.

III. Pesticide Types

INSECTICIDES

INORGANIC

Inorganic insecticides are naturally occurring chemical substances that do not contain the element carbon and, thus, are not derived from living things. Some of the first pesticides ever used were elements such as *sulfur* or *arsenic*. Inorganic pesticides in general are slow-acting, but have the advantage of having long-term residual activity. Sulfur is still used for thrips control in citrus.

ORGANIC

Organic insecticides contain the element carbon, which is the element common to all living things. Some organic insecticides are derived from living things, and others are synthetic (man-made). **Synthetic** insecticides are manufactured chemicals that have been modified from biological sources, and selected for biological activity, then manufactured. For example, organophosphates were initially discovered in Germany during World War II by chemists looking for a substitute for nicotine.

Chlorinated hydrocarbons (also called *organochlorines*) were the first widely used group of synthetic insecticides. Developed during World War II, they are made up of the elements carbon, hydrogen, and chlorine. An example of a chlorinated hydrocarbon is DDT (dichlorodiphenyltrichloroethane), which was used extensively throughout the world for many years. For a number of reasons, it was banned for use in the United States in 1971. In fact, Arizona was the first state to limit its use because of problems with contaminated milk in dairies.

Most pesticides are attacked by heat, microorganisms, water, or ultraviolet light after they are applied and eventually break down into compounds that are not biologically active. Chlorinated hydrocarbons, on the other hand, do not readily break down, but bind to soil particles. Because they persist for a long time, they are more likely to pollute the environment by leaching into the groundwater and by accumulating in the fatty tissues of nontarget organisms (see **bioaccumulation,** Chapter 4). Currently, **none** of the following are registered for use: *chlordane*, *methoxychlor* and *dicofol* (an acaricide).

Organophosphates were developed to replace some of the chlorinated hydrocarbons. Organophosphates break down more rapidly in the environment and are less likely to pose an environmental risk. However, they are, in general, more acutely toxic than chlorinated hydrocarbons. Organophosphates contain the element phosphorus linked to oxygen to form the phosphate group. *Methyl parathion* and *chlorpyrifos* are commonly used organophosphates.

Carbamates were first developed in the 1950's. They contain carbon atoms linked to nitrogen and oxygen. In general, they break down more rapidly than organophosphates and have fairly high mammalian toxicity. *Aldicarb, carbofuran,* and *carbaryl* are carbamates.

Pyrethroids were developed by chemists by modifying the basic chemical structure of the botanical insecticide *pyrethrum*, originally extracted from the flowers of a chrysanthemum (Fig 3.2). Known for having a quick knockdown of insects, pyrethroids (or synthetic pyrethroids) break down under ultraviolet light. More recent pyrethroids have been modified to last longer in sunlight. Among these, *permethrin* and *fenvalerate* are examples.

Figure 3.2 Chrysanthemum

Insect Growth Regulators (IGRs) stimulate or disrupt growth or development in insects. Juvenile hormone analogues are compounds that mimic **juvenile hormone**, a natural insect hormone involved in controlling molting and other processes in insects. An example of a juvenile hormone analogue is MTDD. MTDD is a hormone-like compound in the wood of balsam fir which prevents insects from developing to the adult stage.

Biological

Biological control is the use of living organisms, particularly natural enemies, parasites, and pathogens, to control or manage pests. As a certified applicator or pesticide handler, you must be aware of predators such as the ladybird beetle, that feeds on aphids, as well as parasites that consume their hosts. But pathogens and their by-products are also used to manage insects; examples are microbial and botanical insecticides found in living organisms.

Microbial insecticides are microorganisms or microbes that control insect pests. For example, *Bacillus thuringiensis* (Bt) a bacterium sprayed onto host plants, contains a toxin known to disrupt the gut of caterpillars feeding on the plants. In addition, scientists have taken the gene that controls the production of the toxin and inserted it into cotton and other plants. Now the genetically engineered plants are able to defend themselves against lepidopteran insect pests.

Many plants contain materials that deter feeding by insects or act as **botanical** insecticides. For example, *pyrethrum*, the oily extract of certain varieties of chrysanthemum, has been put to use by humans; our modern synthetic pyrethroids are based on the chemistry of pyrethrum. It is important to note, however, that other botanical insecticides, such as *sabadilla, rotenone,* and *nicotine,* even though derived from plants, are not necessarily less toxic to humans or other animals. For example, *rotenone* is highly toxic to fish, *nicotine* is a Category I insecticide, the same category containing *methyl parathion*.

HERBICIDES

Herbicides are used to control weeds. A weed is any plant that is out of place. For example, a corn plant in a field of cotton would be a weed.

Herbicides may be selective or nonselective. A **selective** herbicide controls only specific types of plants. For example, 2,4-D will kill annual grasses and mustard in a barley field. On the other hand, **non-selective** herbicides may be used to control all the vegetation in an area.

Herbicides may be applied at different times in the plant growth cycle. **Preplant** herbicides are applied *before a crop is planted*. **Preemergence** herbicides are applied to plants *before they emerge* from the ground; **postemergence** herbicides are applied to plants that have *already emerged*.

If a herbicide is **persistent**, it can continue to be active for more than a growing season, and thus could harm susceptible plants or interfere with crop rotation.

INORGANIC

As with insecticides, the earliest herbicides were inorganic materials such as salt or ash. Arsenic salts such as *sodium arsenite* were widely used as herbicides until the 1960's. *Copper sulfate* is still used to control algae in irrigation water conveyance systems.

ORGANIC

Petroleum Oils were the first organic herbicides. Materials such as used motor oil, kerosene, and diesel, once applied to keep areas weed free, are no longer recommended because they contaminate groundwater and are a fire hazard.

Carbamates are herbicides as well as insecticides and fungicides. They are commonly used as preemergence herbicides, although some have postemergence activity (e.g., *chlorpropham*).

Triazines are commonly available as herbicides. Triazines are made up of carbons and nitrogens forming a six-sided ring. A classic example is the herbicide *atrazine*. The soil sterilant *prometryn* is also a triazine. In general, these herbicides migrate easily in the soil, which may cause leaching problems and affect adjacent plants.

Phenoxy herbicides were developed in the 1940's, and are also called "chlorphenoxy" herbicides because they contain the element chlorine. Phenoxy herbicides mimic **auxins**, natural plant hormones used as growth regulators (e.g., *2,4-D).*

Amides contain the element nitrogen. Generally simple molecules that break down readily and do not persist in the soil, amides may be used as post- or preemergence applications. Some inhibit root elongation in seedlings, and others interrupt photosynthesis (e.g., *propanil).*

Dinitroaniline (or *substituted aniline*) herbicides, like the amides, contain the element nitrogen, but the nitrogen atoms are linked to oxygen. These herbicides interfere with enzymes produced by the plant and inhibit root or shoot growth (e.g., *Treflan*©).

Substituted ureas block the photosynthesis process. Examples are *diuron* and *monuron*.

Plant growth regulators (PGRs) are also used to control weeds. Auxins, giberellins, cytokinins, ethylene generators, and growth retardants all affect growth and fruit ripening of plants.

IV. Pesticide Formulations

Pesticides come in various formulations. Formulations enable the pesticide to be applied. A pesticide formulation can be a wettable powder (WP), soluble powder (SP), or emulsifiable concentrate (EC). Pesticide formulations are broken-down into active ingredients and inert ingredients. The **active ingre-**

dients in a pesticide are the chemicals that control the target pest. Most pesticide products you buy also have **inert** (inactive) **ingredients**, which are used to dilute the pesticide or to make it safer, more effective, easier to measure, mix, or apply, and more convenient to handle. Usually the pesticide is diluted in water, a petroleum-based solvent, or another diluent. Other chemicals in the product may include wetting agents, spreaders, stickers, or extenders. (Fig 3.3)

Figure 3.3 Various Formulations

Some formulations are ready for use. Others must be further diluted with water, a petroleum-based solvent, or air (as in airblast or ULV applications) before they are applied.

A single active ingredient is often sold in several different kinds of formulations. To choose the best available formulation for your pest control situation, ask yourself the following questions about each formulation:

- Do I have the necessary application equipment?
- Can the formulation be applied safely under the conditions in the application area (e.g., drift, runoff, wind, rain)?
- Will the formulation reach your target and stay in place long enough to control the pest?
- Is the formulation likely to harm the surface to which I will apply it?

To answer these kinds of questions, you need to know something about the characteristics of different types of formulations (liquid, dry, or fumigant) and the general advantages and disadvantages of each type.

V. Liquid Formulations

Emulsifiable Concentrates (EC or E)

These formulations usually contain a liquid active ingredient, one or more petroleum-based solvents, and an agent that allows the formulation to be mixed with water to form an emulsion. Each gallon of EC usually contains 25% to 75% (2 to 8 pounds) active ingredient. EC's are among the most versatile formulations. They are used against agricultural, ornamental, turf, forestry, structural, food processing, livestock, and public health pests. They are adaptable to many types of application equipment, including small portable sprayers, hydraulic sprayers, low-volume ground sprayers, and mist blowers. (Fig 3.4)

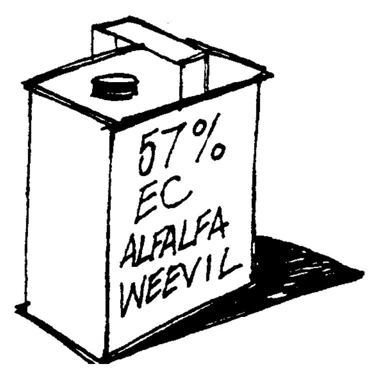

Figure 3.4 Emulsifiable Concentrates (EC or E)

Advantages:

- Relatively easy to handle, transport, and store
- Little agitation required and will not settle out or separate when equipment is running
- Non-abrasive
- Will not plug screens or nozzles
- Leaves little visible residue on treated surfaces.

Disadvantages:

- High concentration makes it easy to overdose or underdose through mixing or calibration errors
- May cause unwanted harm to plants
- Easily absorbed through skin of humans or animals
- Solvents may cause rubber or plastic hoses, gaskets, and pump parts and surfaces to deteriorate
- May cause pitting or discoloration of painted finishes
- Flammable (should be used and stored away from heat or open flame)
- May be corrosive
- Insoluble in water

Solutions (S)

Some pesticide active ingredients dissolve readily in liquid solvents such as water or a petroleum-based solvent. When mixed with the solvent, they form a solution that will not settle out or separate. Formulations of these pesticides usually contain the active ingredient, the solvent, and one or more other ingredients. Solutions may be used in any type of sprayer.

Ready-to-Use (RTU). These solutions contain the correct amount of solvent when you buy them. No further dilution is required before application. These formulations, usually in petroleum-based solvents, contain small amounts (often 1% or less) of active ingredient per gallon.

Concentrate Solutions (C or LC). These must be further diluted with a liquid solvent before you apply them. Occasionally the solvent is water, but more often the solvent is a specially refined oil or petroleum-based solvent. Some uses include livestock and poultry pest control, space sprays in barns and warehouses, shade tree pest control, as well as mosquito control.

Advantages:

- No agitation necessary

Disadvantages:

- Limited number of formulations of this type available

The other advantages and disadvantages of solutions vary depending on the solvent used, the concentration of the active ingredient, and the type of application involved.

Ultra-Low-Volume (ULV). These concentrates may approach 100% active ingredient. They are designed to be used as is or to be diluted with only small quantities of specified solvents. These special-purpose formulations are used in agricultural, forestry, ornamental, and mosquito control programs. (Fig 3.5)

Advantages:

- Relatively easy to handle, transport, and store
- Little agitation required
- Not abrasive to equipment
- No plugging of screens and nozzles
- Leave little visible residue on treated surfaces

Figure 3.5 Ultra-Low-Volume (ULV)

Disadvantages:

- Difficult to keep pesticide in the target site (high drift hazard)
- Specialized equipment required
- Easily absorbed through skin of humans or animals
- Solvents may cause rubber or plastic hoses, gaskets, and pump parts and surfaces to deteriorate

Flowables (F or L)

Some active ingredients are insoluble solids. These may be formulated as flowables in which the finely ground active ingredients are mixed with a liquid, along with inert ingredients, to form a **suspension**. Flowables are mixed with water for application and are similar to EC or wettable powder formulations in ease of handling and use. They are used in the same types of pest control for which EC's are used.

Advantages:

- Seldom clog nozzles
- Easy to handle and apply

Disadvantages:

- Require moderate agitation
- May leave a visible residue

Aerosols (A)

These formulations contain one or more active ingredients and a solvent. Most aerosols contain a low percentage of active ingredient. There are two types of aerosol formulations: the ready-to-use type, and those made for use in smoke or fog generators. (Fig 3.6)

Ready-to-Use Aerosols

These aerosol formulations are usually small, self-contained units that release the pesticide when the nozzle valve is triggered. The pesticide is driven through a fine opening by an inert gas under pressure, creating fine droplets. These products are used in greenhouses, in small areas inside buildings, or in localized outdoor areas. Commercial models, which hold 5 to 10 pounds of pesticide, are usually refillable.

Advantages:

- Ready to use
- Easily stored
- Convenient way to buy small amount of a pesticide
- Retain potency over fairly long time

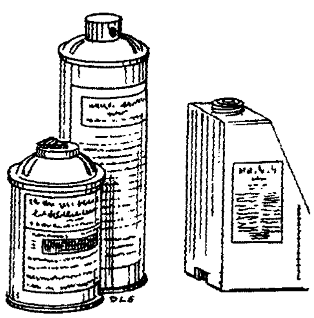

Figure 3.6 Aerosols

Disadvantages:

- Practical for very limited uses
- Risk of inhalation injury
- Hazardous if punctured, overheated, or used near an open flame
- Difficult to confine to target site or pest

Formulations for Smoke or Fog Generators

These aerosol formulations are not under pressure. They are used in machines that break the liquid formulation into a fine mist or fog (aerosol) using a rapidly whirling disk or heated surface. These formulations are used mainly to control insect pests in structures such as greenhouses and warehouses, and to control mosquitoes and biting flies outdoors.

Advantages:

- Easy way to fill entire space with pesticide

Disadvantages:

- Highly specialized use and equipment
- Difficult to confine to target site or pest
- May require respiratory protection to prevent risk of inhalation injury

Invert Emulsions

This mixture contains a water-soluble pesticide dispersed in an oil carrier. Invert emulsions require a special kind of emulsifier that allows the pesticide to be mixed with a large volume of petroleum-based carrier, usually fuel oil. When applied, invert emulsions form large droplets that do not drift easily. Invert emulsions are most commonly used in vegetation control where drift to susceptible nontarget plants is a problem.

VI. Dry Formulations

Dusts (D)

Most dust formulations are ready to use and contain a low percentage of active ingredient (usually 0.5% to 10%), plus a very fine dry inert carrier made from talc, chalk, clay, nut hulls, or volcanic ash. The size of individual dust particles is variable.

A few dust formulations are concentrates and contain a high percentage of active ingredient. These must be mixed with dry inert carriers before they can be applied.

Dusts are always used dry, and they easily drift into non-target sites. They are widely used in seed treatment. Dusts also are used to control lice, fleas, and other parasites on pets and livestock.

Advantages:

- Usually ready to use, with no mixing
- Effective where moisture from a spray might cause damage
- Require simple equipment

Disadvantages:

- Easily drift off target during application
- Residue easily moved off target by air movement or water
- May irritate eyes, nose, throat, and skin
- Do not stick to surfaces as well as liquids

Baits (B)

A bait formulation is an active ingredient mixed with food or another attractive substance. The bait either attracts the pests or is placed where the pests will find it. Pests are killed by eating the pesticide the bait contains. The amount of active ingredient in most bait formulations is quite low, usually less than 5%.

Outdoors they are used to control snails, slugs, and some insects, but their main use is for control of vertebrate pests such as rodents, other mammals, and birds. (Fig 3.7)

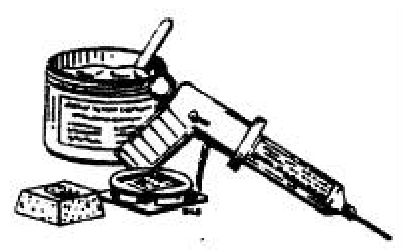

Figure 3.7 Baits

Advantages:

- Ready to use
- Entire area need not be covered because pest goes to bait
- Control pests that move in and out of an area

Disadvantages:

- Can be attractive to children and pets
- May kill domestic animals and non-target wildlife outdoors
- Pest may prefer the crop or other food to the bait

- Dead pests may cause odor problem
- Other animals may be poisoned as a result of feeding on the poisoned pests

If baits are not removed when the pesticide becomes ineffective, they may serve as a food supply for the target pest or other pests.

Granules (G)

Granular formulations are similar to dust formulations except that granular particles are larger and heavier. The coarse particles are made from an absorptive material such as clay, corn cobs, or walnut shells. The active ingredient either coats the outside of the granules or is absorbed into them. (Fig 3.8) The amount of active ingredient is relatively low, usually ranging from 1% to 15%.

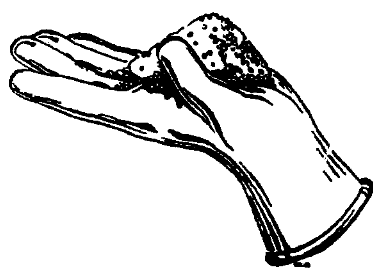

Figure 3.8 Granular Formulation

Granular pesticides are most often used to apply chemicals to the soil to control weeds, nematodes, and insects living in the soil. Granular formulations are sometimes used in airplane or helicopter applications to minimize drift or to penetrate dense vegetation.

Granular formulations also are used to control larval mosquitoes and other aquatic pests. Granules are used in agricultural, structural, ornamental, turf, aquatic, right-of-way, and public health (biting insect) pest control operations.

Advantages:

- Ready to use; no mixing
- Drift hazard is low, and particles settle quickly
- Little hazard to applicator (no spray, little dust)
- Weight carries the formulation through foliage to target
- Simple application equipment, such as seeders or fertilizer spreaders
- May break down more slowly than WPs or ECs through a slow-release coating

Disadvantages:

- Do not stick to foliage or other nonlevel surfaces
- May need to be incorporated into soil or planting medium
- May need moisture to start pesticidal action
- May be hazardous to non-target species, especially waterfowl and other birds that mistakenly feed on the grainlike or seedlike granules

Pellets (P or PS)

Most pellet formulations are very similar to granular formulations; the terms often are used interchangeably. In a pellet formulation, however, all the particles are the same weight and shape. The uniformity of the particles allows them to be applied by precision applicators such as those being used for precision planting of pelleted seed. A few fumigants are formulated as pellets; however, these will be clearly labeled as fumigants and should not be confused with nonfumigant, granule-like pellets. (Fig 3.9)

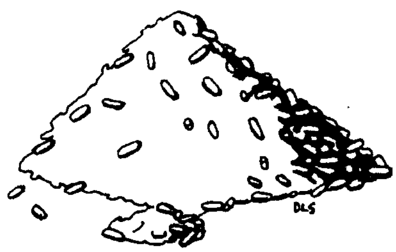

Figure 3.9 Pellets

Wettable Powders (WP or W)

Wettable powders are dry, finely ground formulations that look like dusts. They usually must be mixed with water for application as a spray. A few products, however, may be applied either as a dust or as a wettable powder — the choice is left to the applicator. Wettable powders contain 5 % to 95% active ingredient, usually 50% or more. Wettable powder particles do not dissolve in water. They settle out quickly unless constant agitation is used to keep them suspended.

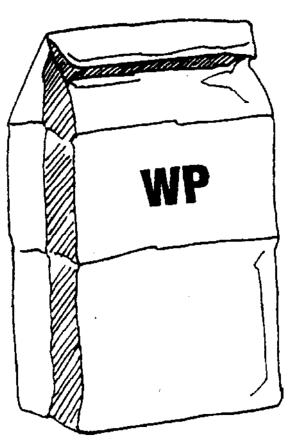

Figure 3.10 Wettable Powder

Wettable powders are one of the most widely used pesticide formulations. They can be used for most pest problems and in most types of spray equipment where agitation is possible. (Fig 3.10)

Advantages:

- Easy to store, transport, and handle
- Less likely than ECs and other petroleum-based pesticides to cause unwanted harm to treated plants, animals, and surfaces
- Easily measured and mixed
- Less skin and eye absorption than ECs and other liquid formulations

Disadvantages:

- Inhalation hazard to applicator while pouring and mixing the concentrated powder
- Require good and constant agitation (usually mechanical) in the spray tank and quickly settle out if agitation is turned off
- Abrasive to many pumps and nozzles, causing them to wear out quickly
- Difficult to mix in very hard or very alkaline water
- Often clog nozzles and screens
- Residues may be visible

Soluble powders (SP or WSP)

Soluble powder formulations look like wettable powders. However, when mixed with water, soluble powders dissolve readily and form a true solution. After they are mixed thoroughly, no additional agitation is necessary. The amount of active ingredient in soluble powders ranges from 15% to 95%; it usually is over 50%. Soluble powders have all the advantages of wettable powders and none of the disadvantages except the inhalation hazard during mixing. Few pesticides are available in this formulation, because few active ingredients are soluble in water.

Microencapsulated Pesticides (M)

Microencapsulated formulations are particles of pesticides (liquid or dry) surrounded by a plastic coating. The formulated product is mixed with water and applied as a spray. Once applied, the capsules slowly releases the pesticide. The encapsulation process can prolong the active life of the pesticide by providing a timed release of the active ingredient.

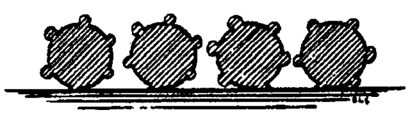

Figure 3.11 Microencapsulated

Advantages:

- Increased safety to applicator
- Easy to mix, handle, and apply
- Releases pesticide over a period of time

Disadvantages:

- Constant agitation necessary in tank
- Some bees may pick up the capsules and carry them back to their hive where the released pesticide may poison the entire hive.

Water-Dispersible Granules or Dry Flowables (WDG or DF)

Water-dispersible granular formulations are like wettable powder formulations, except the active ingredient is prepared as granule-sized particles. Water-dispersible granules must be mixed with water to be applied. Once in water, the granules break apart into fine powder. The formulation requires constant agitation to keep it suspended in water. Water-dispersible granules share the advantages and disadvantages of wettable powders except that they are more easily measured and mixed, and they cause less inhalation hazard to the applicator during pouring and mixing.

Abbreviations for Formulations

A	=	Aerosol
AF	=	Aqueous Flowable
AS	=	Aqueous Solution or Aqueous Suspension
B	=	Bait
C	=	Concentrate
CM	=	Concentrate Mixture
CG	=	Concentrate Granules
D	=	Dust
DF	=	Dry Flowable
DS	=	Soluble Dust
E	=	Emulsifiable Concentrate
EC	=	Emulsifiable Concentrate
F	=	Flowable

G	=	Granules
H/A	=	Harvest Aid
L	=	Flowable
LC	=	Liquid Concentrate or Low Concentrate
LV	=	Low Volatile
M	=	Microencapsulated
MTF	=	Multiple Temperature Formulation
P	=	Pellets
PS	=	Pellets
RTU	=	Ready to Use
S	=	Solution
SD	=	Soluble Dust
SG	=	Soluble Granule
SP	=	Soluble Powder
ULV	=	Ultra Low Volume
ULW	=	Ultra Low Weight or Ultra Low Wettable
WS	=	Water Soluble
WSG	=	Water-Soluble Granules
WSL	=	Water-Soluble Liquid
W	=	Wettable Powder
WDG	=	Water-Dispersible Granules
WP	=	Wettable Powder
WSP	=	Wettable Soluble Powder

VII. Fumigants

Fumigants are pesticides that form poisonous gases when applied. Some active ingredients are liquids when packaged under high pressure but change to gases when they are released. Other active ingredients are volatile liquids when enclosed in an ordinary container and so are not formulated under pressure. Still others are solids that release gases when applied under conditions of high humidity or in the presence of water vapor. Fumigants are used in food and grain storage facilities; regulatory pest control at ports of entry and at state and national borders; in soil, and in greenhouses, granaries, and grain bins.

Advantages:

- Toxic to a wide range of pests
- Can penetrate tightly packed areas such as soil or grains
- Single treatment usually will kill most pests in treated area

Disadvantages:

- The target site must be enclosed or covered to prevent the gas from escaping
- Highly toxic to humans and all other living organisms
- Require the use of specialized protective equipment, including respirators
- Require the use of specialized application equipment

VIII. Adjuvants

An **adjuvant** is a chemical added to a pesticide formulation or tank mix to increase its effectiveness or safety. Most pesticide formulations contain at least a small percentage of adjuvants. Some of the most common adjuvants are surfactants, surface active ingredients that alter the dispersing, spreading, and wetting properties of spray droplets. (Fig 3.12)

Adjuvants include:

- **Wetting Agents** – allow wettable powders to mix with water

- **Emulsifiers** – allow petroleum-based pesticides (ECs) to mix with water
- **Invert Emulsifiers –** allow water-based pesticides to mix with petroleum carrier
- **Spreaders** – allow pesticide to form a uniform coating layer over the treated surface
- **Stickers** – allow pesticide to stay on the treated surface

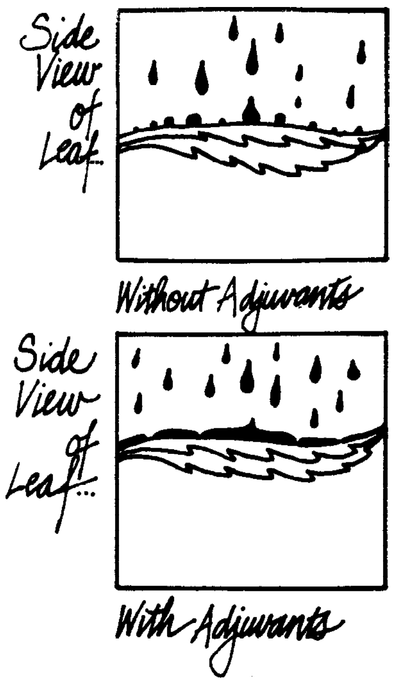

Figure 3.12 Use of Adjuvant

- **Penetrants** – allow the pesticide to get through the outer surface to the inside of the treated area
- **Foaming Agents** – reduce drift
- **Thickeners** – reduce drift by increasing droplet size
- **Safeners** – reduce the toxicity of a pesticide formulation to the pesticide handler or to the treated surface
- **Compatibility Agents** – aid in combining pesticides effectively
- **Buffers** – allow pesticides to be mixed with diluents or other pesticides of different acidity or alkalinity
- **Anti-Foaming Agents** – reduce foaming of spray mixtures that require vigorous agitation

IX. Pesticide Mixtures

Tank Mixing and pH

Pesticides can be tank mixed to reduce application costs and increase effectiveness while providing broader control. However, compatibility of the pesticides is important. **Compatibility** is the ability of two or more chemicals to be combined without danger. Compatibility can be influenced by the **pH** — the acidity or alkalinity — of a solution. A neutral solution has a pH of 7. Various pesticides are unstable in **alkaline** solutions (pH greater than 7), but quite stable in solutions that are slightly **acidic** (pH of approximately 6). The best pH for most pesticides is about 6, although a solution range of 6 to 7 is satisfactory. In addition, tank mixing can be influenced by various products. For example, **buffers** are substances capable of changing the pH of a water solution to a prescribed level, maintaining it even though conditions such as water alkalinity may change. **Acidifiers** are acids that can be added to spray mixtures to neutralize alkaline solutions and lower the pH.

Compatibility: The Jar Test

Pesticides should be mixed in small quantities to test for compatibility problems. You can check or verify incompatibility using a jar test. The procedure is as follows:

A. Wearing label-prescribed protective clothing, measure a pint of intended spray water into a quart glass jar;

B. Add ingredients in the following order and stir well:

   1. Surfactant
   2. Compatibility agents and activators
   3. Wettable powders and dry flowable formulations
   4. Water-soluble concentrations and solutions
   5. Emulsifiable concentrations and flowable formulations
   6. Soluble powders
   7. Any adjuvants

C. For each ingredient (e.g., wettable power), you add 1 teaspoon per unit (pint or pound) per 100 gallons of final spray mixture;

D. After mixing, let stand for 15 minutes;

E. Stir and observe the results.

Compatible: Smooth mixture that combines well after stirring.

Incompatible: Mixture separates out, contains clumps, and is grainy in appearance. Check label and other literature for possible solutions to incompatible mixtures.

X. Chemical Changes

Pesticides may mix properly in solution but the effectiveness or toxicity of the pesticides in the mixture can change. These interactive effects are due to the chemical rather than the physical properties of the solution. For example, an **additive effect** occurs when two or more pesticides mixed together are no more toxic to the target pest than any of the pesticides used alone. **Potentiation** occurs when a pesticide becomes more toxic because something mixed with it lowers the pest's tolerance to the chemical. For example, impurities in *malathion* make it more toxic because they inactivate enzymes produced by the pest that normally detoxify malathion. **Synergism** occurs when a chemical (with or without pesticide properties) increases the toxicity of a pesticide when mixed with it. For example, *piperonyl butoxide* has no insecticidal properties but is used to increase the toxicity of pyrethrum insecticides. **Deactivation** occurs, usually in the spray tank, at the time the pesticides are combined, as when one alters the pH or causes hydrolysis.

Chapter Three
Pesticide Types & Formulations — Question and Answer Review

1. Q. What is a pesticide?

A. A **pesticide** is any chemical used to control pests. A pesticide is any substance or mixture of substances intended for destroying, preventing or mitigating insects, rodents, nematodes, fungi or weeds, or any other form of life declared to be pests.

2. Q. What is a pesticide formulation?

A. A pesticide formulation is the mixture of active and inert (inactive) ingredients that form a pesticide product.

3. Q. Is "insecticide" another word for pesticide?

A. No. **Insecticide** specifically kills insects and is just one of many types of pesticides.

4. Q. What is the difference between *active* ingredients and *inert* ingredients?

A. *Active* ingredients are the chemicals in a pesticide product that control pests. *Inert* ingredients are the chemicals in a pesticide product that are added to make the product safer; more effective; easier to measure, mix, and apply; and more convenient to handle.

5. Q. What are the common abbreviations for these types of formulations?

1. Dust ______
2. Emulsifiable concentrate ______
3. Granules ______
4. Microencapsulated ______
5. Soluble powder _____
6. Solution _____
7. Wettable powder _____

A. 1. D; 2. EC; 3. G; 4. ME; 5. S; 6. SP; 7. WP.

6. Q. What types of factors should you consider when you have a choice of formulations for a pest control task?

A. You should consider the characteristics of each formulation and which of the formulation's advantages and disadvantages are important in your application situation. You should also ask yourself the following: Do you have the right application equipment? Can you apply the formulation safely? Will the formulation reach the target and stay in place long enough to control the pest? Might the formulation harm the target site?

7. Q. If you had a choice of either a wettable powder formulation or a granular formulation for a particular pest control task, which would be best if drift were a major concern? Which would be best if you needed the pesticide to stay on a surface that is not level, such as foliage?

A. The granular formulation would be the best choice in the first situation, because granules have a much lower drift hazard than wettable powders. Granules do not stick to non-level surfaces, so the wettable powder would be the best choice in the second situation.

8. Q. If you had a choice of either a wettable powder or an emulsifiable concentrate for a particular pest control task, which would be better if you were concerned about harming the treated surface? Which would be best if you were diluting with very hard or alkaline water?

A. The wettable powder would be the best choice in the first situation, because ECs are corrosive and may cause pitting, discoloration, or other damage to treated surfaces. Because wettable powders are difficult to mix in very hard or very alkaline water, the EC formulation would be the best choice in the second situation.

9. Q. Why are adjuvants sometimes added to pesticide formulations?

A. *Adjuvants* are added to a pesticide formulation or tank mix to increase its effectiveness or safety.

10. Q. What is an adjuvant?

A. An Adjuvant is a chemical added to the pesticide mixture that helps an active ingredient do a better job.

11. Q. What type(s) of adjuvants should you consider for (1) reducing drift; (2) coating a surface evenly; and (3) for combining two or more pesticides in one application?

A. (1) Foaming agents and thickeners help to reduce drift; (2) spreaders help to coat the treated surface with an even layer of pesticide; and (3) compatibility agents aid in combining pesticides effectively.

12. Q. What is the recommended pH level for most pesticide sprays?

A. The best pH for most pesticides is about 6, although a range of 6 to 7 is satisfactory.

13. Q. Why would you choose a low-concentrate liquid formulation if you wanted to be sure of getting the right mixture?

A. Low-concentrate formulations are designed to be sprayed as purchased.

14. Q. Which formulation is most hazardous to the applicator because it is highly concentrated and absorbed easily by the skin?

A. Emulsifiable concentrate.

15. Q. How does a systemic insecticide act on a pest?

A. A systemic pesticide flows inside the plant to all of its parts and kills the insects that eat the plant.

16. Q. Define potentiation, synergism, and additive effect.

A. *Potentiation:* An increase in the toxicity of the pesticide.
Synergism: The total effect is greater than the sum of the independent effect.
Additive effect: Combining two or more pesticides, and the resulting toxicity is not more than the amount of either pesticide.

17. Q. What advantages do granules have over dusts and sprays?

A. Granules drift less and are applied with simple, often multi-purpose equipment. They can work their way through dense foliage to a target underneath.