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Pesticides and Formulation Technology

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Pesticide Products and the Modern Marketplace

There is a seemingly endless variety of pesticide products sold in the urban and agricultural marketplace. Casual observation in any hardware store or lawn and garden center will reveal that variations extend even to products that are manufactured by the same chemical company and contain the same ingredients.

Manufacturers often produce various forms of a pesticide to meet different pest control needs. For example, an insecticide may be applied as a liquid to control adult Japanese beetles on rose bushes and as a solid material for suppressing the larval (grub) stage of that insect in turf. Applying the insecticide as a liquid spray permits contact with the adult beetle, while the solid form can be watered into the root zone of the lawn where the grubs live.

A pesticide product consists of two parts: active and inert ingredients. Active ingredients are chemicals which actually control the pest. Inert ingredients are primarily solvents and carriers that help deliver the active ingredients to the target pest; they serve to enhance the utility of the product. Inert ingredients may be liquids into which the active ingredient is dissolved, chemicals that keep the product from separating or settling, and even compounds that help secure the pesticide to its target after application.

The combination of an active ingredient with compatible inert ingredients is referred to as a formulation. Pesticides are formulated for a number of different reasons. A pesticide active ingredient in a relatively pure form, ready for manufacturers' use, rarely is suitable for field application. An active ingredient usually must be formulated in a manner that

- Increases pesticide effectiveness in the field;
- Improves safety features;
- Enhances handling qualities.

The formulation gives the product its unique physical form and specific characteristics, enabling it to fill a market niche. There are approximately 900 pesticide active ingredients formulated into 20,000 pesticide products sold and used in the United States today. For most practical purposes, the terms *formulation* and *product* can be used interchangeably.

An Overview of the Formulation Process

The active ingredients in pesticide products come from many sources. Some, such as nicotine, pyrethrum, and rotenone, are extracted from plants. Others have a mineral origin, while a few are derived from microbes. However, the vast majority of active ingredients are synthesized (man-made) in the laboratory. These synthetic active ingredients may have been designed by an organic chemist or discovered through a screening process of chemicals generated by various industries.

Regardless of their source, pesticide active ingredients have different solubilities. Some dissolve readily in water, others only in oils. Some active ingredients may be relatively insoluble in either water or oils. These different solubility characteristics, coupled with the intended use of the pesticide, in large measure define the types of formulations in which the active ingredient may be delivered.

It is preferable from the manufacturer's perspective to use the active ingredient in original form, when possible (e.g., a water soluble active ingredient formulated as a water soluble concentrate). When this is not feasible, it may become necessary to alter the active ingredient in order to change its solubility characteristics. This would be done, obviously, in a manner that did not detract from the pesticidal properties of the active ingredient.

Usually, an active ingredient will be combined with appropriate inert materials prior to packaging. A brief review of some basic chemistry terminology should prove helpful in understanding differences among the various types of formulations.

Sorption

In some cases it may be necessary or desirable to adhere a liquid active ingredient onto a solid surface (e.g., a powder, dust, or granule). This process is called sorption and it can be accomplished by two possible mechanisms:

- Adsorption—a chemical/physical attraction between the active ingredient and the surface of the solid.
- Absorption—entry of the active ingredient into the pores of the solid.

Solution

A solution results when a substance (the solute) is *dissolved* in a liquid (the solvent). The solute can be a solid or a liquid. The components of a true solution cannot be mechanically separated. Once mixed, a true solution does not require agitation to keep its various parts from settling. Solutions are frequently transparent. An example of a solution is the active ingredient in the herbicide Roundup PRO: glyphosate (solute) dissolved in water (solvent).

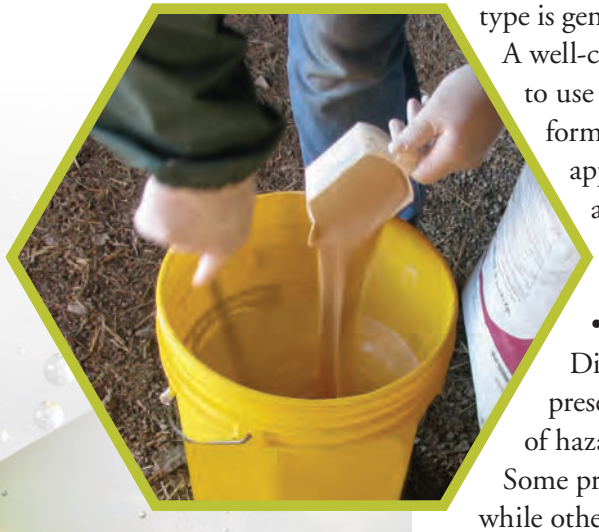
Suspension

A suspension is a mixture of finely divided, solid particles *dispersed* in a liquid. The solid particles do not dissolve in the liquid, and the mixture must be agitated to maintain thorough distribution. Most suspensions will have a cloudy appearance. The herbicide Spike 80W is formulated as a wettable powder. This product forms a suspension when mixed with water for application as a spray. Label information describes the need for sufficient agitation to keep the product dispersed in the spray tank.

Emulsion

An emulsion is a mixture that occurs when one liquid is dispersed (as droplets) in another liquid. Each liquid will retain its original identity and some degree of agitation generally is required to keep the emulsion from separating. Emulsions usually will have a "milky" appearance. The insecticide Demon EC is formulated as an emulsifiable concentrate. The active ingredient is dissolved in an oil-based solvent. When the product is mixed with water, an emulsion is formed. An emulsifying agent in the formulated product helps prevent the emulsion from separating by surrounding the oil droplets that contain the dissolved active ingredient.

Formulation Selection Considerations



The importance of formulation type is generally overlooked. A well-considered decision to use the most appropriate formulation for a given application will include an analysis of the following factors.

• ***Applicator safety.*** Different formulations present various degrees of hazard to the applicator. Some products are easily inhaled, while others can penetrate skin or cause injury when splashed in the eyes.

• ***Environmental concerns.*** Special precautions need to be taken with formulations that are prone to drift in air or move off target into water. Wildlife can also be affected to varying degrees by different formulations. Birds may be attracted by granules, and fish or aquatic invertebrates can prove especially sensitive to specific pesticide formulations.

• ***Pest biology.*** The growth habits and survival strategies of a pest will often determine what formulation provides optimum contact between the active ingredient and the pest.

• ***Available equipment.*** Some pesticide formulations require specialized handling equipment. This includes application equipment, safety equipment, and spill control equipment.

• ***Surfaces to be protected.*** Applicators must be aware that certain formulations can stain fabrics, discolor linoleum, dissolve plastic, or burn foliage.

• ***Cost.*** Product prices may vary substantially, based on the ingredients used and the complexity of delivering active ingredients in specific formulations.

Individuals such as commercial pest control technicians or farmworkers who may not be involved in the selection process but are responsible for the actual application also should be very aware of the type of formulation they are using. As stated, formulation type can have an impact on hazards to human health and the environment. Inattention to the type of formulation being used could mean the difference between a routine application and one that is the source of environmental contamination—or worse, a serious human exposure.

Common Pesticide Formulations

Formulations are classified as solids or liquids on the basis of their physical state in the container at the time of purchase. A formulation can contain more than one active ingredient and many have to be further diluted with an appropriate carrier (e.g., water) prior to use.

Solid Formulations

Solid formulations can be divided into two types: ready-to-use; and concentrates, which must be mixed with water to be applied as a spray. The properties of six solid formulations are described in this publication. Three of the solid formulations (dusts, granules, and pellets) are ready-to-use, and three (wettable powders, dry flowables, and soluble powders) are intended to be mixed with water.

Dusts

Dusts are manufactured by the sorption of an active ingredient onto a finely-ground, solid inert such as talc, clay, or chalk. They are relatively easy to use because no mixing is required and the application equipment (e.g., hand bellows and bulb dusters) is lightweight and simple. Dusts can provide excellent coverage, but the small particle size that allows for this advantage also creates an inhalation and drift hazard. Dusts are generally applied as spot treatments for insect and disease control outside. Commercial pest control operators use dusts effectively in residential and institutional settings for control of various insect pests. Indoors, this type of formulation permits the delivery of an insecticide into cracks and crevices, behind baseboards and cabinets, etc. Thus, the insecticide is placed into the pest's habitat and away from contact by people and pets.

Granules

The manufacture of granular formulations is similar to that of dusts except that the active ingredient is sorbed onto a larger particle. The inert solid may be clay, sand, or plant materials. A granule is defined by size: Granule-sized products will pass through a 4-mesh (number of wires per inch) sieve and be retained on an 80-mesh sieve. Granules are applied dry and usually are intended for soil applications where they have the advantage of weight to carry them through foliage to the ground below. The larger particle size of granules, relative to dusts, minimizes the potential for drift. There is also a reduced inhalation hazard, but some fine particles are associated with the formulation.

In addition, granules have a low dermal hazard. The primary drawbacks of granules are their bulk, the problems they present in handling, and the difficulty inherent in achieving uniform application. Granules also may have to be incorporated into the soil to work, and they are sometimes attractive to nontarget organisms such as birds.

Dusts

Granules

Pellets

Pellets

Pellets are very similar to granules, but their manufacture is different. The active ingredient is combined with inert materials to form a slurry (a thick liquid mixture). This slurry is then extruded under pressure through a die and cut at desired

lengths to produce a particle that is relatively uniform in size and shape. Pellets are typically used in spot applications. Pelleted formulations provide a high degree of safety to the applicator. They do have the potential to roll on steep slopes and thereby harm nontarget vegetation or contaminate surface water.

Wettable Powders

Wettable powders are finely divided solids, typically mineral clays, to which an active ingredient is sorbed. This formulation is diluted with water and applied as a liquid spray. The mixture forms a suspension in the spray tank. Wettable powders will likely contain wetting and dispersing agents as part of the formulation. These are chemicals used to help wet the powder and disperse it throughout the tank. Wettable powders are a very common type of formulation. They provide an ideal way to apply (in spray form) an active ingredient that is not readily soluble in water. Wettable powders tend to pose a lower dermal hazard in comparison to liquid formulations, and they do not burn vegetation as readily as oil-based formulations. This formulation can present an inhalation hazard to the applicator during mixing because of the powdery nature of the particles. Furthermore, there are a series of disadvantages associated with all formulations that form a suspension in the spray tank: They require agitation to prevent settling out; they can be abrasive to equipment; and they may cause strainers and screens to plug.

Wettable powder before mixing

Wettable powder after mixing

Dry Flowables

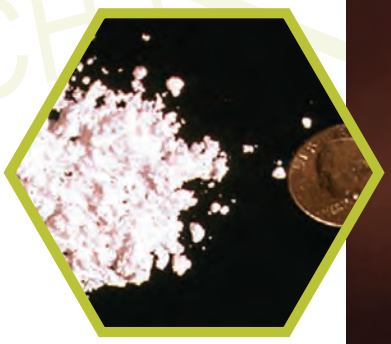
Dry flowables—or water dispersible granules, as they are sometimes called—are manufactured in the same way as wettable powders except that the powder is aggregated into granular particles. They are diluted with water and applied in a spray exactly as if they were a wettable powder. Dry flowables form a suspension in the spray tank; they have basically the same advantages and disadvantages as wettable powders, with several important exceptions. During the mixing process, dry flowables pour more easily from the container and, because of their larger particle size, reduce inhalation hazard to the applicator. *Note: The labels of some dry flowables do permit application of the product in the dry state.*

Dry flowable before mixing

Dry flowable after mixing

Soluble Powders

Soluble powders, although not particularly common, are worth mentioning in contrast with the wettable powders and dry flowables. Their lack of availability is due to the fact that not many solid active ingredients are soluble in water; those that do exist (formulated as soluble powders) are mixed with water in the spray tank, where they dissolve and form a true solution prior to spraying. Soluble powders provide most of the same benefits as wettable powders, without the need for agitation once dissolved in the tank. They are also nonabrasive to application equipment. Soluble powders, like any finely divided particle, can present an inhalation hazard to applicators during mixing.



Soluble powder before mixing

Soluble powder after mixing

Liquid Formulations

Descriptions of four common liquid formulations that are mixed with a carrier follow. The carrier generally will be water, but in some instances labels may permit the use of crop oil, or some other light fuel oil as a carrier.

Liquid Flowables

The manufacture of liquid flowables (also called flowables or suspension concentrates) mirrors that of wettable powders—with the exception that the powder, dispersing agents, wetting agents, etc., are mixed with water before packaging. The result is a suspension requiring further dilution with water before use. The product is applied as a spray, with all the advantages of a wettable powder. The benefit of this formulation is that there is no inhalation hazard to the applicator during mixing since the powder already is suspended in water, permitting it to be poured. Liquid flowables form a suspension in the spray tank and have the same potential problems inherent in any suspension. However, they usually do not require constant agitation during application due to the extremely small size of the suspended particles. One further problem noted with this formulation is the difficulty in removing all of the product from the container during the triple rinsing process.

Microencapsulates

Microencapsulates consist of a solid or liquid inert (containing an active ingredient) surrounded by a plastic or starch coating. The resulting capsules can be sold as dispersible granules (dry flowables), or as a liquid formulation. Encapsulation enhances applicator safety while providing timed release of the active ingredient. Liquid forms of microencapsulates are further diluted with water and applied as sprays. They form suspensions in the spray tank and have many of the same properties as liquid flowables.

Emulsifiable Concentrates

Emulsifiable concentrates consist of an oil-soluble active ingredient dissolved in an appropriate oil-based solvent to which an emulsifying agent is added. Emulsifiable concentrates are mixed with water and applied as a spray. As their name implies, they form an emulsion in the spray tank. The emulsifying agents allow oil-soluble active ingredients to be sprayed in water as a carrier. Some agitation is typically required to maintain dispersion of the oil droplets. They are not abrasive to application equipment, nor do they plug screens and strainers. Emulsifiable concentrates have several disadvantages: They present a dermal hazard; they can penetrate oily barriers like human skin; they usually have an odor problem; they can burn foliage; and they can cause the deterioration of rubber and plastic equipment parts.

Liquid flowable before mixing

Liquid flowable after mixing

Microencapsulate before mixing

Microencapsulate after mixing

Solutions

Solutions (water-soluble concentrates) consist of water-soluble active ingredients dissolved in water, for sale to the applicator for further dilution prior to field application. They will obviously form a true solution in the spray tank and require no agitation after they are thoroughly dissolved. Solutions are not abrasive to equipment and will not plug strainers and screens. There are several major herbicides with wide-scale use that are formulated as solutions. They include products containing paraquat, glyphosate, and 2,4-D. Solutions have few disadvantages; however, some that are produced as dissolved salts can be caustic to human skin.

Miscellaneous Liquid Formulations

Most liquid formulations are designed to be mixed with a carrier before application. However, some products are sold ready-to-use (RTU). This type of formulation generally will have a low concentration of active ingredient. Typically, the container also serves as the application device.

Low and ultra low volume (ULV) concentrates used in specialty situations (e.g., space spraying and fogging) are frequently applied undiluted. Dermal hazards are a problem when mixing these products because of the high concentration of active ingredient. Low and ultra low volume concentrated formulations utilize special equipment to deliver the product in the form of very tiny droplets. Consequently, while they provide excellent coverage, drift potential and inhalation problems during application can be quite high.

Aerosols and Fumigants

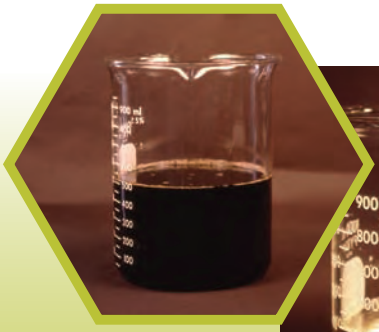
Aerosols and fumigants are frequently confused, yet they have very different properties and uses.

Aerosols really refer to a delivery system that moves the active ingredient to the target site in the form of a mist of very small particles: solids or liquid drops. The particles can be released under pressure or produced by fog or smoke generators. Aerosols are especially useful for indoor insect control, as coverage is thorough. But it can be difficult to confine the aerosol to the target area, and there is always the danger of inhalation.

Fumigants deliver the active ingredient to the target site in the form of a *gas*. Some fumigants are solids that turn into a gas in the presence of atmospheric moisture. Others are liquids under pressure that vaporize when the pressure is released. Fumigants can completely fill a space, and many have tremendous penetrating power. They can be used to treat objects (e.g., furniture), structures, grain, and even soil for pest insects and other vermin. Fumigants are among the most hazardous pesticide products to use due to their inhalation danger.

Emulsifiable concentrate before mixing

Emulsion after mixing



Solution before mixing

Solution after mixing

Formulations and Label Information

Product labels often will convey information about how the pesticide is formulated by a suffix to the brand or trade name. The table below lists many of these suffixes and their meanings. A suffix can also include a number that indicates the amount of active ingredient in the product. The number contained in the brand name suffix of a solid formulation such as a dust, granule, wettable powder, etc., describes the percent of active ingredient in that product on a *percent by weight* basis. For example, the brand name Tempo 20WP® tells the purchaser that the product is formulated as a wettable powder and that it is 20 percent active ingredient, *by weight*. The number included in the brand name suffix of a liquid formulation such as a liquid flowable or an emulsifiable concentrate describes the amount of active ingredient in the product on the basis of *pounds per gallon*. The brand name Pendulum 3.3EC® indicates that the product is formulated as an emulsifiable concentrate and that it contains 3.3 pounds of active ingredient per gallon of product.

Exceptions to these rules of thumb are common. Read the pesticide label carefully for a precise description of how the product is formulated.

Formulation	Suffix
Dust	**D**
Granule	**G**
Pellet	**P, PS**
Wettable Powder	**W, WP**
Dry Flowable	**DF**
Water Disperable Granule	**WDG**
Soluable Powder	**S, SP**
Liquid Flowable	**L, F**
Suspension Concentrate	**SC**
Microencapsulate	**M**
Emulsifiable Concentrate	**E, EC**

Synergists

Synergists are chemicals that can boost the pesticidal activity of an active ingredient. The combination of a synergist with the active ingredient provides a degree of pest control greater than what would be expected from the simple additive effects from each compound. Synergists are used with a variety of pesticides including insecticides, nematicides, and fungicides. Synergists typically have little, if any, activity against the pest when used alone. However, EPA policy is to include synergists in the active ingredient statement on the product label.

A common example of a synergist is piperonyl butoxide. This chemical synergizes pyrethrin insecticides. It is believed to function by slowing down the insect pest's ability to metabolize (detoxify) pyrethrin, resulting in fewer insects recovering from exposure to the insecticide.

Adjuvants

An adjuvant is *any* compound that facilitates the action of pesticides or modifies characteristics of pesticide formulations or spray solutions. The terminology for pesticide additives is confusing. It is often assumed that any material that lowers the surface tension of water (i.e., a surfactant) in the spray mixture or increases the wettability of the spray solution on surfaces is an adjuvant.

Adjuvants are used in pesticide spray solutions as

- Wetting agents
- Penetrants
- Spreaders
- Co-solvents
- Stickers
- Stabilizing agents

It is obvious that the term *adjuvant* encompasses a wider meaning than wetting agent or surfactant. There are many adjuvants that have little, if any, effect on pesticidal activity. These types of adjuvants include

- Anti-foam agents
- Buffering agents
- Compatibility agents
- Drift control/deposition aids

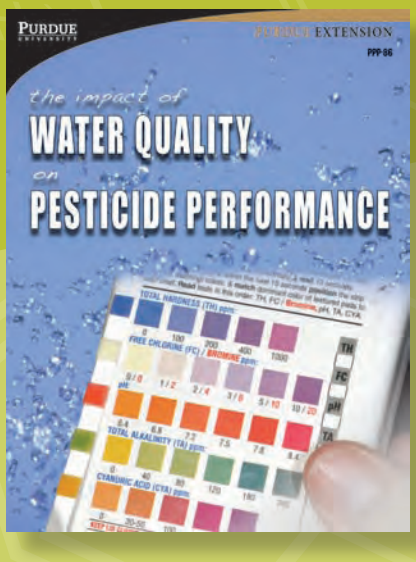
Adjuvants are included in pesticide formulations as part of the total product which is sold by the manufacturer, or as an additive to be mixed with pesticide products in the spray tank. Adjuvants can be classified according to their type of action. There are three basic kinds:

- Activator adjuvants include surfactants, wetting agents, penetrants, and oils. Activator agents are the best known class of adjuvants because they are normally purchased separately by the user and added to the pesticidal solution in the spray tank.
- Spray modifier agents include stickers, film formers, spreaders, spreaders/stickers, deposit builders, thickening agents, and foams.
- Utility modifiers include emulsifiers, dispersants, stabilizing agents, coupling agents, co-solvents, compatibility agents, and anti-foam agents.

Spray modifier agents and utility modifier agents usually are found as part of the pesticide formulation and thus are added to the pesticide product by the manufacturer.

Summary

The proper selection of a formulation is a critical step in any pest control process involving pesticides. It is an important management decision that has an impact on profitability, customer satisfaction, human safety, and environmental quality. An understanding of the properties of various formulations has as much significance to the applicator as it does to the supervisor. The applicator performs the duties of mixing as well as application. Applicators come into close contact with both the concentrated and diluted product. A simple, personal interest in one's good health, and that of others, dictates the need to know the safety properties of the formulation being used. Furthermore, a concern for environmental quality reflected in a responsible application requires a familiarity with the attributes of a given formulation and the potential impact its use might have on the surroundings. Understanding the formulation allows one to maximize its benefits while reducing the risks.



A related publication for suggested reading:

The Impact of Water Quality on Pesticide Performance

(Purdue Extension publication PPP-86). It is available at: **www.ppp.purdue.edu/Pubs/PPP-86.pdf**. Multiple copies may be ordered from the Purdue Extension Education Store: **www.extension.purdue.edu/store**.

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