

## PESTICIDE FORMULATIONS

Pesticide products (the products you purchase from your supplier) consist of two parts: active ingredients and inactive ingredients. The active ingredient (AI) is the chemical that actually “controls” the pest, whether by killing it or affecting its physiological development. The inert ingredients (sometimes more than one in a given product) are usually solvents or carriers that help package the active ingredient in such a way that it can be applied reasonably safely.

Every pesticide active ingredient has a specific molecular structure that dictates several physical characteristics. Some are soluble in water, while others are soluble in oils. Some are relatively insoluble in either water or oils. Some are quite persistent, while others break down quickly. Some volatilize quickly, while others are relatively stable at higher temperatures. Formulators generally try to use the active ingredient in its original form, if possible – for example, a water-soluble AI formulated as a water-soluble concentrate.

A pesticide *formulation* is a combination of one or more active ingredients with compatible inert ingredients. An unformulated active ingredient (one that is in a relatively pure form) is rarely suitable for use by pesticide applicators, and certainly is not suitable for use by homeowners. A pesticide must be formulated in a way that increases pesticide effectiveness in the field, improves safety features (often related to toxicology and exposure), and makes it easier to use. There are approximately 900 pesticide active ingredients in the United States, and they have been formulated into nearly 20,000 different pesticide products. (*Formulation* and *product* are often used interchangeably.)

Much of the information that follows is found in *Pesticides and Formulation Technology*, Purdue Extension PPP-31, Purdue University Pesticides Program. ([www.extension.purdue.edu/extmedia](http://www.extension.purdue.edu/extmedia).) As always, a pesticide applicator must be sure to follow all the guidance on the pesticide label, including use of personal protective equipment (PPE). In particular, the label will contain information about the mixing and loading process, and will identify products that are especially likely to settle out of solution during the application process, and therefore must be agitated throughout the application. Be sure to adhere to all guidance provided on the label regarding the mixing process, as well as the need for agitation. **The label is the law** – failure to follow label instructions can result in loss of license, fines, and/or imprisonment.

### Chemistry terminology

A little terminology is helpful to understand the following descriptions of formulations. These terms are also important to understand when trying to determine which pesticides can be combined in a “**tank mix**” (a combination of two or more pesticides or fertilizers that are applied at the same time).

**Sorption** refers to the process of adhering a liquid active ingredient on to a solid surface (e.g., a dust or a granule). Adsorption occurs when there is a chemical or physical attraction between the AI and the surface of the solid. Absorption occurs when the AI enters pores on the solid.

A **solution** occurs when a substance (the solute) is dissolved in a liquid (the solvent). The solute can be a solid or a liquid. Once a solution forms, the solute and the solvent cannot be mechanically separated. (An everyday example is table salt that has dissolved in water.)

A **suspension** occurs when very fine solid particles disperse in a liquid. The solid particles do not dissolve in the liquid, and the liquid must be agitated to maintain thorough distribution (and to avoid the particles settling to the bottom of the tank).

An **emulsion** is a mixture that occurs when one liquid is dispersed (as small droplets) in another liquid. Each liquid retains its original identity. Several pesticides are formulated as “emulsifiable concentrates”, where the AI is dissolved in an oil-based solvent and then added to water in the spray tank.

## **FORMULATIONS THAT ARE APPLIED DRY (“READY-TO-USE”)**

Some pesticides are applied directly out of the container, including dusts, granules, and pellets. These formulations are NOT added to water and applied with a sprayer, but instead are applied using a spreader.

### **DUSTS**

Dusts are produced by the sorption of an AI onto a finely-ground, solid inert material such as talc, clay, or chalk. They are usually applied as spot treatments for insect and disease activity on foliage of ornamentals. They are not common in golf course maintenance, but are mentioned here for comparison to other formulations.

#### **Advantages**

Dusts are easy to use because there is no mixing involved and application equipment (e.g., bulb dusters) is light-weight and simple to use. They can provide excellent coverage because of the fineness of the particles.

#### **Disadvantages**

Dusts are highly susceptible to drift, even in light winds, and can therefore pose an inhalation hazard.

### **GRANULES**

The pesticide active ingredient is sorbed onto particles that are larger than dusts. Granules can pass through a 4-mesh sieve (four wires per inch) and are retained on an 80-mesh sieve, so there is a wide range of particle sizes. Some granules are quite coarse, while others are relatively fine. Granules are often formulated in such a way that only 1 to 10% of the product is active ingredient. The inert solid may be clay, sand, byproducts of plant material (e.g., corn cob), or polymer-coated pellets (“dissolvable” plasticized beads). In most cases, the granule begins to break down when it is exposed to water, and the active ingredient, whether pesticide or fertilizer, is released from the granule.

#### **Advantages**

Because of the inherent dilution in the formulation (usually no more than 10% active ingredient), dermal exposure hazards are usually lower than many of the sprayable formulations. Because granules are larger than dusts (and usually denser as well), they are much less likely to drift and the inhalation hazard is lower than it is for dusts or

wettable powders. If you have a spreader, granules are easy to apply. (**NOTE** that some pesticides, including the long-since banned Nematicur™, were highly toxic even though they were formulated as granules, so even though a product is available in a granular formulation, it still might be toxic to handle.)

#### **Disadvantages**

It takes more space to store granules than other formulations, because the product is only 1 to 10% active ingredient. That means the remainder of the product (90 to 99%) consists of inert ingredients. It is sometimes difficult to achieve uniform coverage with granules.

### **PELLETS**

Some dry formulations that are intended to be applied dry (like granules) are manufactured by producing a slurry of the active ingredient and inert ingredients, then extruding the slurry through a narrow tube that cuts the cylinder at regular intervals. The result is a particle that is relatively uniform in size and shape. The advantages and disadvantages of pellets are similar to those of granules, but the round-sided pellets can bounce and roll on steep slopes.

### **FORMULATIONS THAT ARE APPLIED IN WATER (“SPRAYABLE”)**

Some sprayable formulations are solids (wettable powders, soluble powders, dry flowables), while others are liquids (flowables, microencapsulates, emulsifiable concentrates, solutions). All are diluted in water in a sprayer, and applied as a liquid spray. Many of these “sprayable” formulations can settle in the tank, so it is important to be sure the agitation system is operating correctly and providing plenty of agitation/mixing of the pesticide and the water in the tank throughout the application.

### **WETTABLE POWDERS**

Wettable powders (WP) are very fine solids, often mineral clays, to which an active ingredient has been sorbed. The mixture forms a suspension in the spray tank. WPs usually contain wetting and dispersing agents to aid in the dispersal of the product throughout the tank. Most WPs in the turf industry contain 50 to 80% active ingredient and 20 to 50% inert ingredients.

#### **Advantages**

WPs usually pose a lower dermal hazard in comparison to liquid formulations because they are less readily absorbed through the skin, and they are less likely to cause phytotoxicity than oil-based formulations.

#### **Disadvantages**

WPs are very fine powders and can pose an inhalation hazard when mixing and loading. The powder “bounces” off the surface of the water in the sprayer during the mixing process, and this can release particles into the air. Wettable powders are very susceptible to settling in water, so the tank must be agitated constantly to prevent the product from settling out. WPs can be abrasive to the equipment; and nozzles, strainers, and screens may plug up. WPs may leave visible residues on the plants.

### **SOLUBLE POWDERS (SPS)**

Soluble powders (SPs) are superficially similar to wettable powders but the active and inert ingredients dissolve and form a true solution in water. They are uncommon because very few solid AIs are soluble in water.

**Advantages**

The SPs form a true solution in the tank, so they tend to spread through the water in the tank more readily. They tend to be less abrasive to application equipment than WPs.

**Disadvantages**

SPs pose the same inhalation and other hazards as WPs during handling and mixing.

**DRY FLOWABLES (DF) AND WATER DISPERSIBLE GRANULES (WDG)**

Dry flowables (DF) and water dispersible granules (WDGs) are produced like wettable powders, but the powder is subsequently aggregated into granular particles. They form a suspension in the spray tank. The advantages and disadvantages are similar to those of WPs. Some notable exceptions:

**Advantages (in addition to WP advantages)**

DFs and WDGs are much less dusty than WPs so they do not pose nearly as much of an inhalation hazard during mixing and handling. The product pours easily from the container, so there is less likelihood of spills. Spills are easier to clean up than liquid spills. Dermal hazard is lower than for WPs, because the “granules” or pellets tend to bounce off the skin.

**Disadvantages (in addition to WP disadvantages)**

DFs and WDGs are even more likely to settle in the tank than wettable powders, so constant agitation is even more critical than for most other formulations. They are also more likely to cause abrasion to the equipment and to clog nozzles and screens.

**FLOWABLES (F) OR SUSPENSION CONCENTRATES (SC)**

Flowables are produced when an active ingredient is sorbed to a fine particle to form a powder. This powder, along with various inert ingredients (e.g., dispersing agents, wetting agents), is mixed with water before packaging. The resulting liquid appears cloudy in the container and must be further diluted in water in the spray tank before it is applied. The suspended particles are usually much smaller than those in a WP.

**Advantages**

Flowables normally do not leave long-term visible residues on the plants. They protect the plant as long as emulsifiable concentrates, but are much less likely to be phytotoxic. They are less hazardous than oil-based liquids because they are less likely to be absorbed through the skin, and they are less hazardous than wettable powders because the inhalation hazard is much lower.

**Disadvantages**

Flowables can settle in the container and need some agitation in the sprayer during the application. Some applicators report difficulty removing all of the product from the container during the triple rinsing process.

**EMULSIFIABLE CONCENTRATES (ECs)**

Emulsifiable concentrates (ECs) contain an active ingredient that is soluble in oil that is then dissolved in an appropriate oil-based solvent. An emulsifying agent is added to aid in the dispersal of the product in water. They form an emulsion in the spray tank. The

liquid in the container is usually clear, but becomes cloudy when it mixes with water in the sprayer.

**Advantages**

ECs usually do not leave long-term visible residues on the plants. The sprayer can be adjusted to spray finer droplet sizes than most other sprayable formulations. (Small droplets can improve the uniformity of coverage on the foliage, but they are also more likely to drift off the site.) ECs usually have a longer residual on the surface of the plants than WPs, and do not wash off leaves as readily as WPs. They are less abrasive to application equipment than several other formulations, and they do not plug nozzles or screens.

**Disadvantages**

ECs present the highest dermal hazard of all the formulations, because the oil-based liquid can penetrate skin readily. They often have a distinct odor that can persist for a while after an application. They are more likely to be phytotoxic than other formulations. In addition, they can cause deterioration of rubber and plastic equipment parts. In addition, they must be agitated, especially early in the mixing and loading process.

**SOLUTIONS**

Solutions are water-soluble liquid concentrates that include a water-soluble AI dissolved in water. They are then further diluted in a sprayer before application.

**Advantages**

Like the soluble powders, they form a true solution in the spray tank. They are less likely to be abrasive to equipment than many other formulations, and will not plug nozzles and screens.

**Disadvantages**

Some solutions that are formulated as dissolved salts can be caustic to human skin.

**Reference:**

Martin, Andrew, Fred Whitford, and Tom Jordan. 2011. *Pesticides and Formulation Technology*, Purdue Extension PPP-31, Purdue University Pesticides Program.  
([www.extension.purdue.edu/extmedia](http://www.extension.purdue.edu/extmedia).)