A variety of formulation types are available for pesticide products, and multiple types of formulations may be available for a given active ingredient chemistry. Understanding the physical properties of the various formulations is vital to using them correctly and getting the best performance. This article is intended to review the fundamentals of some of the primary formulation types that a pesticide user might encounter and perhaps serve as a reference when questions about formulations arise.

As all formulation types have advantages and disadvantages, this article is intended as an objective review of the various formulation types and associated issues and does not seek to persuade users to select one type over another. Furthermore, although this article discusses various formulation practices, nothing in it should be construed as advocating engaging in any formulation practice or practicing any technique without obtaining the required licenses and observing all advisable precautionary measures for the handling of pesticide products.

**Flowable or suspension concentrate (FL or SC)**

**Description**

A flowable formulation contains tiny particles of active ingredient suspended in a liquid (usually water) and milled to reduce the average particle size. For active ingredients that are more dense than water (most are), suspension agents are added to prevent the solids from settling in the packaged product. Among other inert components, wetting agents are usually needed to keep the solid surfaces wetted in water because most active ingredients tend to be hydrophobic.

**Physical properties**

Flowables typically have a higher viscosity (are “thicker”) than water alone, because of the presence of thickeners/suspension aids. Developing a flowable is a balancing act between the need to keep the viscosity high enough that particles do not sink rapidly, but low enough that the material pours out or pumps easily. Upon dilution in a spray tank, the solids disperse in the water.

**What to watch out for**

Upon dilution in water, the suspension aids also get diluted; thus, the solids can then settle quickly to the bottom of the mix tank. Clearly, it is critical that agitation be maintained on dilution. Depending on the formulation, the solids can be difficult to resuspend once they have settled.

In addition, it is important to prevent air entrapment in the system, which can lead to foaming. When air bubbles get trapped in water as in the case of foam, wetting agents can migrate away from the surface of the active ingredient and toward the air-water interface of the bubbles. This can cause the active ingredient to “de-mix” from the water, forming aggregates that clog strainers or stick to tank surfaces.

When tank-mixing a flowable or suspension concentrate with emulsifiable concentrates, it is important to watch out for a phenomenon called *heterogeneous flocculation*, in which the solid crystals of a flowable or suspension concentrate get incorporated into the emulsified oil droplets, again leading to large aggregates or clumps. Finally, it is good practice to shake or mix flowables in their container well before use, especially if this is recommended on the product packaging/label.

**Emulsifiable concentrate (EC)**

**Description**

An emulsifiable concentrate is a solvent-
based (oil) system that contains active ingredients dissolved in a solvent and emulsifiers. It is designed to form an oil-in-water emulsion upon dilution.

Physical properties
Because ECs are solvent-based, the physical properties can vary widely depending on the solvent system used. The solvent type can affect product qualities such as odor, viscosity, flammability and potential for phytotoxicity. Upon dilution in water, the solvent or oil phase forms an emulsion in water that will eventually separate out. The formation of this emulsion is often referred to as creaming. The oil droplets coalesce, forming larger droplets, eventually separating out (think oil-and-vinegar salad dressing). The time over which this occurs can vary with different products.

What to watch out for
Order of addition is important when tank-mixing ECs. For proper dispersion of all components, emulsifiable concentrates should be added last when tank-mixing multiple formulations. ECs may be more phytotoxic to plants than other formulations. Sometimes this is purely an effect of the solvent system used; other times the solvent may allow an active ingredient from another tank-mix partner to penetrate plant tissues too easily or quickly. This is especially problematic for active ingredients that are intended to remain on the leaf surface and not penetrate plant tissues.

Suspoemulsion (SE)
Description
A suspoemulsion is a water-based product that contains both suspended solids (like an SC) and emulsion droplets (like an EC after dilution). As with SCs, suspension aids are needed to prevent settling of the solids or creaming of the emulsion droplets. These tend to be among the more difficult formulations to design properly.

Physical properties
Suspoemulsions have viscosities much higher than water. They are designed to disperse readily upon dilution in water. Like SCs, they require good agitation after dilution to maintain a homogenous dispersion.

What to watch out for
One potential problem with SEs is a phenomenon known as heterogeneous flocculation. Very strong agitation in a spray tank can cause the solids to penetrate the oil droplets, leading to flocculation that can, in the most severe cases, lead to clumping of the particles and screen blockage. A well-designed SE should be devoid of this problem, but other tank-mix partners could increase the likelihood of occurrence, even for a very robust system. As with SCs, agitation should be maintained upon dilution in a spray tank.

Wettable powder (WP)
Description
WPs are dry formulations containing the active ingredient, often a carrier and other ingredients. They are milled to reduce the particle size to facilitate spraying without clogging nozzles and are designed to disperse in water upon dilution. After dilution, they are similar to flowables in that they exist as solids suspended in water. For this reason, it is important to have adequate agitation because the solids will settle upon dilution. WPs are sometimes packaged in water-soluble bags for ease of handling.

Physical properties
WPs are finely milled powders and can be dusty. They generally do not flow easily, which means it may be necessary to scoop out the material for use if it is not contained in a water-soluble pouch.

What to watch out for
WPs that are not contained in water-soluble packaging can be very dusty. Wearing the proper protective equipment (for example, dust masks) will prevent inhalation of the finely milled particles. WPs packed in water-soluble pouches should always be added to a mix tank first, and the pouch should be allowed to fully dissolve before other tank-mix partners are added. Failure to do so can result in incomplete dissolution of the pouch, which can clog sprayer strainers.

Water-dispersible granule (WG or WDG)
Description
Water-dispersible granules are dry formulations that are similar to WPs except they consist of larger particles and are typically much less dusty. After dispersion in water, they form a suspension of solids. For this reason, adequate agitation must be maintained to prevent settling of the solids.

Physical properties
WGs tend to flow easily, which allows them to be poured, rather than scooped out of a package. The ease of dispersion is highly formulation-specific, and well-designed WGs should disperse fairly quickly.

What to watch out for
Though WGs are usually less dusty than WPs, there can be smaller particles present, sometimes due to attrition (breaking up) of granules during transportation/handling. A well-designed system should be devoid of this problem. WGs usually take more time to fully

GLOSSARY

Air entrainment — The inclusion of air into a liquid by mechanical means.

Flocculation — A phenomenon in which particles aggregate and clump together.

Heterogenous flocculation — Aggregation of two dissimilar particle types, for example, a solid particle aggregating with emulsified oil droplets.

Micelles — Tiny aggregates of surfactants in a liquid that can contain a second liquid or molecule that is insoluble in the surrounding liquid. For example, detergents form micelles in water to trap oils and dirt so they can be washed away.

Micron — One millionth of a meter (about 0.00004 inch). The average human hair is about 100 microns in diameter.

— R.C.
A variety of formulation types are available for pesticide products. Formulations may be liquid or solid, powders or granules, water-based or oil-based. Understanding the physical properties of the various formulations is vital to using them correctly and getting the best performance. Small-scale compatibility tests can prevent tank-mixing errors. Product labels provide information on proper use.

Conclusions

Achieving the best performance from pesticides requires some basic understanding of the physical properties of various formulation types. Applying this knowledge can help minimize the occurrence of problems encountered when using these products. Given the wide variety of formulation types available and potential problems when tank-mixing, small-scale compatibility tests (jar tests) are a way to discover problems before making large batches for spraying. This is particularly important when a new tank-mix combination is used. Information on proper use of the product should be found in the product label. In addition, some companies offer technical support services that can help solve formulation-related issues.

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