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Agricultural Chemical Drift and Its Control[1]

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Drift is the airborne movement of particles into nontarget areas. It is both undesirable and, to a degree, unavoidable. Drift problems can be minimized by understanding what causes it and following recommended procedures for limiting it.

The fear of chemical drift is out of proportion to the threat that it poses to people and the environment. This statement is supported by a video tape, "*Big Fears, Little Risks*," presented by The American Council on Science and Health. In this video tape, Dr. Bruce Ames, a scientist at the University of California, Berkeley and the developer of the Ames test, a widely used test to determine the carcinogenic nature of chemicals, states that the low levels of chemicals in the environment are much less of a threat to human health than life-style related factors such as smoking, diet, sexual behavior, and others.

What about the threat of chemicals that drift from treated fields and settle directly onto unsuspecting people? Workers in adjacent fields have been accidently sprayed by drift and received a dose sufficient to cause serious illness. However, the safety specialist at both the University of Florida in Gainesville, FL, and the University of California in Davis, CA, two of the more important agricultural states, do not recall any documented cases of a person 's death being caused by spray drift. People have died from accidental poisoning by agricultural chemicals, but they were either mixing or loading the concentrated chemical and were not using procedures recommended on the product label.

Although hazardous pesticide residues on produce grown in the United States is a rare occurrence, it is still a major public concern. A 1984 consumer survey showed that of all the possible harmful products found in food, the public worried most about pesticide residues. Because the public perceives that pesticides in our food supply is a major problem, applicators of pesticidal chemicals should apply them wisely to minimize drift and to avoid drift problems. Some recommended procedures for minimizing drift are presented in this publication.

Note: The remainder of this publication will primarily refer to pesticidal particles as droplets because the majority of pesticides are applied as sprays. However, small particles of dry material are also prone to drift. Pesticidal dusts were once the most common formulation used in agriculture in the late 1940's when the use of synthetic pesticides became a common practice. Dusts are seldom used in

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agriculture today because they are so prone to drift from the target area.

SWATH DISPLACEMENT - LONG RANGE DRIFT

Drift is comprised of two components, "swath displacement" and "long range drift". Swath displacement is the lateral movement of relatively large droplets 150-200 micrometers or larger (spray droplets are measured in micrometers; 1 inch is equal to 25400 micrometers) for a short distance. Swath displacement can cause relatively high residues in nearby fields.

Long range drift is the movement of small droplets for great distances (miles from an application site) and often over a wide area. The resulting level of residue is usually very low, but can cause a problem when the chemical settles on a crop that is highly sensitive to that particular chemical.

FACTORS THAT INFLUENCE DRIFT

The primary factors that influence drift are droplet size, wind speed, humidity, formulation of the pesticide, height of emission (primarily influences swath displacement of large droplets), and the size of the area treated with the pesticide. The factor that has the greatest influence on the downwind movement is droplet size.

Droplet Size

Droplet size is the single most important factor that affects the distance that a droplet will drift from the target area. The vertical velocity (settling velocity) at which a droplet falls to the ground depends on the size of the droplet. The settling velocity varies approximately as the square of a droplet's diameter. A 400 micrometer droplet would fall 4 times as fast as a 200 micrometer droplet and would drift 1/4 as far when transported at equivalent wind speeds.

Wind Speed

Wind speed influences the drift distance of droplets, but does not have as great an influence as droplet size. The distance that a droplet drifts is approximately proportional to the wind speed. A large droplet will travel twice as far in a wind twice as fast.

Humidity

Droplets are reduced in size due to evaporation of the volatile portion of the spray. Therefore, droplets that are not particularly drift-prone during humid conditions might become small enough to drift from the target area when the humidity is low.

Sometimes applicators in the cotton growing regions of the South apply pesticides in as little as 1/2 gallon per acre of crop oils (soybean or peanut oil). Normally the pesticide might be applied in water at a higher rate per acre. The reason that some applicators give for using oil as a diluent is that it does not evaporate; and, therefore, does not pose a drift problem. This is not necessarily true because the small amount of spray applied must be highly atomized to achieve coverage and is drift-prone without the effect of evaporation.

Formulation

Aerial applicators are often called "crop dusters" because most of the pesticides applied during the early years of aerial application (late forties and fifties) were formulated as dusts. Aerial applicators are "crop dusters" in name only in today's agriculture. Most applicators switched to sprays and granular applications to reduce drift problems. Dusts are the most drift-prone pesticide formulation because the particles are very small.

Many pesticides are oil based formulations known as emulsifiable concentrates (EC) because many pesticidal chemicals are soluble in oil. These formulations form a white, milky emulsion when mixed with water. If a large droplet spectrum is used to apply the emulsion, the resulting spray is not particularly drift- prone. If the droplet spectrum produced by the nozzle is small, the water phase of the mixture can evaporate leaving nothing but a small oil droplet that is prone to drift.

Some formulations of pesticides are more volatile than others and the vapor phase of the chemical can drift and cause problems outside of the target area. The herbicide, 2,4-D, is formulated as an

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amine and an ester. The ester formulation is often more effective, but is more volatile. Ester formulations are banned in some areas because some broadleaf crops like tomatoes and melons are extremely sensitive to 2,4-D and even small concentrations of the chemical vapor in a distant nontarget field can cause plant injury.

The least drift-prone formulations of pesticides are pellets and granules. The use of these formulations is somewhat limited because they cannot be used to apply chemicals to plant foliage. They are widely used to apply chemicals to the soil or when treating aquatic weeds.

Height of Emission

The time that large droplets remain airborne and consequently the time that the wind has to act on them depends on the height of the nozzle above the ground.

The emission height of small droplets is not necessarily a major factor in determining distance that it might drift. The weight of a small droplet is very small and it can actually rise rather than fall because upward components of the wind can generate friction forces larger than the droplet's weight. A small droplet can be emitted from a nozzle close to the ground (18 inches or standard boom height) and remain aloft much longer than a larger droplet emitted at a much higher height.

Size of the Treated Area

This factor tends to be overlooked by many applicators of agricultural chemicals. The amount of residue that drifts onto a neighboring crop after treating 10, 20, or 50 acres might not cause damage to the crop, but at some number of acres the residue level can cause damage. Because the amount of residue in surrounding fields depends on the number of acres treated in the target field, an applicator should spread out the treatment of large fields over as many days as feasible. This increases the chances of the drift being spread out by various wind directions at a residue level low enough to avoid crop damage.

The size of the area that can be treated by an aircraft in a short period of time is what causes many drift problems related to aerial application. It is often reasoned that aircraft cause drift problems because of the relatively high height of the spray boom. The height of the spray boom can cause high residues in an adjacent field due to swath displacement, but probably is not a major factor in the level of residue in more distant fields.

Airblast sprayers that are sometimes used to treat low growing crops generally produce a very small, drift-prone droplet spectrum. These sprayers are used because they can cover a wide swath (40 to 80 feet) without a cumbersome wide boom. If enough of these sprayers were placed in a field so that approximately 1000 to 1500 acres could be treated in a day (an acreage treatable by an aircraft), the resulting drift problem in distant fields could be much greater than one caused by an aircraft because there is a greater percentage of small droplets emitted by the sprayers.

NOZZLES PRODUCE A WIDE SPECTRUM OF DROPLETS

Drift would be much less of a problem, if nozzles were available that could produce a narrow range of droplet sizes with no droplets below approximately 150-200 micrometers in diameter. Commercially available hydraulic nozzles produce a wide droplet spectrum with droplets ranging from below 100 up to 500 micrometers and larger. The extremes on both ends of the spectrum are not very effective in controlling most pests. The small droplets are prone to drift from the drift from the target field and the extremely large ones contain a lot of pesticide that does not effectively contribute to plant coverage.

Large droplets are not very effective in achieving plant coverage because the volume of a droplet varies as the cube of the droplet diameter. Neither a 250 nor a 500 micrometer droplet are very prone to drift from the target field because both quickly settle to the ground. A 500 micrometer droplet contains eight times the pesticide as the 250 micrometer droplet and this pesticide would be far more effective, in relation to coverage, if it were in eight 250 micrometer droplets. An ideal nozzle would produce droplets in the 250 to 300 micrometer

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range. These droplets would be large enough to avoid long range drift problems, but small enough to yield acceptable spray coverage. These droplets drift a very short distance because the wind does not have much time to act on them before they reach the ground.

SWATCH DISPLACEMENT IS PREDICTABLE

Swath displacement is usually about 25 feet for low pressure ground sprayers and up to 300 feet for sprays applied by aircraft. Swath displacement is the predictable component of chemical drift and is dependent on the droplet size, the height from which the droplet is released, and the wind speed. If swath displacement was the only component of drift, drift would not be as serious of a problem as it is. A pesticide applicator would merely leave a buffer strip between the last rows of the treated field and an adjacent field that would be wide enough to avoid contaminating the nontarget field.

LONG RANGE DRIFT IS NOT PREDICTABLE

Long range drift of small droplets is not predictable because a small droplet does not always fall while suspended in air. Air can have a vertical velocity component which is generally upward during the middle of the day when the warm air at ground level is displaced by the cooler, heavier air above it. The vertical updraft can cause a friction force on a small droplet that is greater than the droplet's weight. When the upward force exceeds the droplet's weight, the droplet will rise rather than fall. To make matters worse, the weight of a spray droplet reduces over time because water (most spray droplets are predominantly water) in the droplet evaporates.

A small droplet will remain airborne until the air mass transporting the droplet is calm long enough to allow the small downward force of gravity to cause it to settle to the ground. Because weather is unpredictable, accurately predicting where a small airborne droplet will eventually land is essentially impossible. The location is largely a matter of chance. There are computer models used to determine where droplets will settle under given environmental conditions. These models predict the paths taken by the larger droplets, but are not very accurate when predicting where the small droplets settle out. These programs are useful for determining how wide a buffer zone should be to keep swath displacement from causing problems in nearby fields. Fortunately the residue level that accumulates because of long range drift is usually very low and often undetectable.

Whether the low level of chemical that results from long range drift constitutes a problem depends on who is asked. There are some people who feel that chemicals settling on nontarget areas at any level is a problem. If the only acceptable level of drift into nontarget areas was zero, all spray operations would have to be shut down along with many industrial operations. There is no such thing as "zero drift" for any operation where small particles are released into the atmosphere. Even large objects are displaced some small amount when falling in air that has an horizontal wind velocity. However, it is possible to keep drift to a such a low level that the benefits from applying a chemical exceed the potential risks in the minds of most rational people. If this were not so, the application of the chemical would not be allowed by the Environmental Protection Agency (EPA), the agency that regulates agricultural pesticides.

DRIFT CAN OCCUR AT THE TIME OF APPLICATION OR LATER

Chemicals can drift from the target area and cause a drift problem at the time of the application or at some time after the application. Drift that occurs after the application are caused by: (1) having the dry residue of a wettable powder applied as a spray blown into an adjacent area after the water carrier evaporates, (2) having chemical vapors transported downwind or (3) having high winds blow pesticide-treated soil and plant particles from the target field into a neighboring area some time after the chemical was applied. Contamination resulting from a chemical being transported into nontarget areas hours or even days after application are an oddity. Very few of the problems caused by drift have resulted from "post application" drift. This publication is primarily concerned with the drift of particles that begin their flight into neighboring areas at the time of application. This is the type of drift

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that is most prevalent and deserves most of the attention.

DRIFT AND DRIFT PROBLEMS

There is a difference between drift and drift problems. Virtually all spray applications result in some small amount of spray drifting beyond the immediate target area. This does not mean that the drift has created a "problem".

The chemical may drift from the target area onto an area totally within the holdings of the person applying it. This person probably would not consider the drift to be a problem. If the chemical drifts onto a nontarget area not totally within the holdings of the person applying it and the residue level is too small to cause an immediate effect (offensive odor, illness of residents, damage to plants, etc.), there probably will not be a problem caused by the drift. Chemicals used in today's agriculture are less likely to accumulate in the soil or water because the pesticides that are used are degraded by the effects of sunlight and soil microorganisms. Rapid degradation without accumulation of a chemical or its breakdown products is a major consideration in determining whether the chemical can be used as a pesticide.

For example, chemicals that remain as toxins in the environment for a long time (years in some cases) are known as persistent pesticides and the use of this type of chemical has been limited severely by the Environmental Protection Agency. The chlorinated hydrocarbons (DDT is the most renowned chemical in this group) are an example of a pesticide group that remained in the environment for years. These chemicals were very effective pesticides with low mammalian toxicity, but they accumulated over time in the environment. DDT caused the egg shells of birds of prey like the bald eagle to be very thin and they often cracked before the young eaglets hatched.

IPM HAS REDUCED RELIANCE ON CHEMICALS

In Florida, there is probably less drift of chemicals into nontarget areas today than in the past because growers are not relying solely on chemicals to control pests. Growers are using "**Integrated Pest Management (IPM)**" in their fight against pests. IPM is an ecological approach to pest management that often provides economical, long-term protection from pest damage or competition. Concern about pesticides in the environment and their potential harm to users and the public spurred the interest in IPM. The practitioners of IPM use a combination of pest control methods to prevent their crops from suffering economic losses. A few examples of nonchemical pest control methods used by growers are: (1) planting crop varieties that have natural resistance to pests, (2) crop rotations that have proven to be helpful in reducing pest problems, and (3) chopping and burying residues from the previous year's crop.

IPM does not exclude the use of chemical control methods, but chemical use is reserved as the last line of defense in the growers' battle against pests. Sometime data collected in the field show that the pest numbers are high enough to warrant a chemical application to avert serious economic losses in spite of the grower using all of the best nonchemical measures to avoid pest problems. When the decision to apply a chemical is made, growers using IPM try to choose a chemical that will kill the target pest while sparing many of the beneficial insects that prey on various pests in the field. Preserving beneficial insects can prevent or at least delay having to apply chemicals in the future.

DRIFT WILL PROBABLY DECREASE WHILE DRIFT PROBLEMS INCREASE

Even though the application of agricultural pesticides is not increasing in Florida because of the use of IPM (pesticide use in citrus, one of Florida's major crops, has decreased considerably), the number of drift-related problems could increase. Many people are moving to Florida and developments are being built ever closer to long standing agricultural operations. Many of these people are terrified at the thought of an agricultural pesticide, regardless of the level of residue, drifting into their residential area.

A large portion of Florida residents pay to have pest control operators apply levels of pesticides that have been scientifically tested for efficacy and safety

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inside their house and in their yard. If the same level of residue of the chemical occurred in the yard because of spray drifting from an agricultural pest control operation, it would probably be a matter of great concern to residents in the area. This is somewhat perplexing, but understandable. The benefit received from the pest control operator's application is the obvious absence of roaches, fleas, chinch bugs or whatever pest that plagues the homeowner. People do not see the benefit of agricultural pest control "first hand". Even though the public is told that agricultural pesticide use makes for high quality, low cost food, the benefit is not as obvious as the absence of household pests.

Another reason for the strong potential for more drift problems in the future, in spite of possibly less drift, is the relatively new field of Environmental Law coupled with equipment capable of detecting the presence of extremely low levels of any substance.

WHAT CAUSES DRIFT?

The distance that a droplet moves laterally when released in air depends on the time the droplet is airborne and the average horizontal velocity of the droplet during this time period. The distance can be calculated with the equation below:

Drift Distance =suspension time x average horizontal velocity

This equation is simple enough, if you know the time that the droplet is suspended in the air and its average horizontal velocity. However, determining either the suspension time or the average horizontal velocity of small droplets (100-150 micrometers or less) is virtually impossible because they are dependent on weather.

Large Droplets Drift Very Little

The time that a large droplet is suspended in the air depends on the height from which it is released and its average velocity in the vertical direction. A large droplet released in air will fall at an increasing velocity until the droplet's weight is equal to the upward force on the droplet due to air friction. When these two forces are equal, the object will fall at a constant velocity known as the terminal or settling velocity.The terminal velocity of a large droplet is relatively high because it takes high velocities to generate enough friction force to balance the object's weight. Depending on the height from which a large droplet is released, it could strike the ground before reaching its terminal velocity. Large droplets drift very little primarily because their suspension time is small.

Small Droplets Can Drift For Great Distances

The settling velocity of a small droplet is very low because its weight is low. If the droplet is suspended in air that has an updraft velocity greater than the settling velocity of the droplet in still air, the droplet will actually rise rather than fall.

The weight of most spray droplets diminishes with time because the volatile portion of the spray droplet evaporates. Evaporation reduces the weight of small droplets more rapidly than larger ones because they have more surface area relative to their mass. Therefore, a small particle that consists primarily of water is drift-prone initially and becomes even more drift-prone with time.

Because the vertical velocity of small droplets can be either down or up and the wind direction can change during the extended time that a small droplet is suspended, it is virtually impossible to predict the distance that the droplet will drift. Neither the suspension time nor the average horizontal velocity can be predicted with any degree of certainty. A small droplet will either completely vaporize or the nonvolatile portion of the droplet (many spray mixtures contain some small amount of nonvolatile oil) will eventually settle to the ground due to the ever present force of gravity. The air mass carrying the droplet must remain calm for a relatively long time in order for the droplet to settle out.

RECOMMENDATIONS FOR REDUCING DRIFT AND DRIFT PROBLEMS

- Nozzles should be used that produce as large of a droplet spectrum as possible while yielding adequate plant coverage and pest control. Large nozzle orifices and low spray pressure creates a large droplet spectrum. It may be necessary to

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apply higher than normal amounts of diluted spray per acre when using large droplets to avoid drift in order to get adequate coverage.

- Do not make applications during temperature inversions. An inversion is a stable atmospheric condition characterized by an increase in air temperature with an increase in height above the ground until at some height a barrier of cold air is met. Use a column of smoke near the application site to check for an inversion. The smoke will rise to the level of the cold air barrier and will then move laterally below it.

- Usually less material will drift from the target field during an inversion, but the material that does leave the target field remains in a more concentrated cloud and the level of residue that settles onto nontarget areas will be higher than usual. Even though the amount of chemical that drifts from the target area during an inversion is often less, the potential for a drift problem can be greater because the small droplets are not lofted into the upper atmosphere, diluted and spread over a large area.

- Make applications when the wind is blowing away from any highly sensitive nontarget areas and the wind velocity should range between 3 to 10 mph. Extremely low winds are avoided because they indicate inversion conditions and winds above 10 mph are avoided because relatively large droplets can be transported into neighboring fields.

- Leave a buffer zone of approximately 300 feet between the treated field and any particularly sensitive areas. Buffer zones will avoid contamination of neighboring areas by the displacement of relatively large spray droplets. However, buffer zones will not effectively eliminate low level contamination of distant areas by the small droplets formed by all commercially available nozzles.

- The nozzles must provide adequate coverage and pest control while minimizing small, drift prone droplets. Request a droplet spectrum data sheet from the manufacturer that gives information about the percentage of the droplets that are smaller than 150 micrometers. Use nozzles with the smallest portion below this size.

- Use the lowest pressure possible that will give adequate coverage and control to limit the number of drift-prone droplets.

- Make the application at the minimum height that provides a uniform spray pattern.

- Shut off sprayers when turning at the ends of the rows.

- Spray early in the morning, late in the evening, or at night, whenever possible, to avoid killing honey bees.

ADDITIONAL APPLICATIONS FOR AERIAL APPLICATIONS

- Orient the nozzles straight back to minimize small droplet formation due to wind shear.

- Limit the boom length to 75% of the wingspan of the aircraft in order to prevent small droplets from becoming entrained in the wing tip vortices and contributing to drift problems.

- Limit aircraft speed when applying chemicals that crops in neighboring nontarget fields are particularly sensitive to. Modern turbine powered aircraft capable of flying in the 150 to 160 mph range will create more small drift-prone droplets at these speeds.

- Dress the ends of a field with a couple of passes, so that the sprayer does not have to be turned on before the aircraft is level at the beginning of a pass or left on after pulling up at the end of a pass.

- If a customer wants a field treated "now" when conditions indicate a high potential for a drift problem, explain to the customer why it would be unwise to make the application under the existing conditions.