Draft version by Kelly Porter Franklin, January 25 2007

SPRAY DRIFT FROM AERIAL APPLICATION OF PESTICIDES

Overview

This paper attempts to pull the information from many published reports on spray drift into one document with particular emphasis on the conditions existing in CFB Gagetown from 1952 until the present.

Spray drift has only been recognized officially as an enormous problem in recent times. As government regulatory bodies were created to deal with the problem, particularly in the USA, the true scope emerged and funding produced for study. You could say that the 1980's were when it began to hit the fan. It quickly proved true that any spray application results in some escape of the applied formulation beyond the boundaries of the target. In the 1990's government agencies (EPA) and bodies created by industry scrambled to mitigate the effects of spray drift or at least paint it in a better light. In Canada, there still isn't even a Federal agency to call and report an incident of spray drift. (Note: the PRMA will be launching such a facility in the coming months.)

In reading dozens of articles on the subject, one thing stands out clearly: Spraying pesticides from aircraft in modern times is considered a science which is still not fully understood or even recommended in many instances without the use of computers and other advanced instrumentation and training. A cavalier attitude pervades the field as thoroughly as the sprayed chemicals. What then, was the case in the 1950's and 1960's when hundreds of millions of grams of pesticides were sprayed by hired amateurs on places like CFB Gagetown? Do today's computer-controlled, GPS-equipped machines with precision made components spraying formulations for which the physical properties are known bear any resemblance to yesterday's holding up of a wet finger? The answer is yes, and for the same reason – the intractability of highly complex problems of physics in real-time. This paper submits that spray drift catastrophes have always been the norm, and that human health was adversely affected by the herbicide program in CFB Gagetown due to that spray drift.

It must be borne in mind that topographical features have continually changed during that span of time due to the effects of the very chemicals that were sprayed and other activities of man. Canopies were much reduced in height only to regenerate and whole forests were utterly destroyed. Against such an evolving backdrop many topographical factors that influence spray drift would be enhanced or diminished, depending on what time span is examined.

The factors causing spray drift can be summarized in order of importance: Droplet size, wind speed and equipment. All other considerations listed below are minor contributors but can become major if several are present at the same time.

Only fixed wing and helicopter application methods are considered below.

What is spray drift?

No single definition of spray drift exists. For the purpose of this paper, spray drift is defined as the airborne movement of pesticides in either particulate, liquid or vapor form outside the target area where the pesticide was intended to be applied. Pesticide Active Ingredient movement as the result of being transported by water, erosion or as a result of subsequent burning of the created debris is not considered to be spray drift under this definition and these methods of dissemination are not discussed.

There are two basic types of drift, vapor and particle drift. Vapor drift is associated with the volatilization of the pesticide formulation in the form of gases or fumes. Is the applicator responsible for vapor drift? Yes. The applicator should be familiar enough with the product to know if there is a potential for vapor drift. If there is a potential for vapor drift, steps should be taken to avoid this – such as soil incorporation. Particle drift is probably what most people think of when they think of drift. Particle drift is the actual movement of spray particles, usually by wind.

Legal definitions and laws vary regarding spray drift in that some are not prohibitions against drift itself but are rather prohibitions of off site damage.

Spray drift is also known as: Aerial spray plume movement and/or dispersion, downwind movement, off-target spray and chemical trespass. The term *Overspraying* refers to the direct application of pesticides to a non target area and is usually included within the definition of spray drift.

What causes spray drift?

Spray drift can occur if just a few of a large set of contributing conditions are met. For instance, when a typical pesticide formulation of Active Ingredient (AI) plus “inert” ingredients, water and oil is sprayed from an aircraft on a hot day with a light wind, the resulting droplets may be less than 150 microns in diameter (One micron equals 1/25,000 of an inch.) A droplet of this size or less is a candidate for drift. If you could magnify one droplet in this case, you would see that it is a sphere of oil containing the AI surrounded by a layer of water. If this small droplet is aloft long enough for the water layer to evaporate, the resulting even smaller sphere of oil and AI would drift outside the intended area of application in a more concentrated form than what was originally sprayed.

For comparison, a pencil lead is approximately 2000 microns in diameter. A paper clip is 850 microns, a staple is 420 microns, a toothbrush bristle is 300 microns, a sewing thread is 150 microns, and a human hair is approximately 100 microns in diameter.

To put all this in perspective, let’s look at the fate of a droplet 150 microns in diameter (which is the smallest spray size recommended) consisting of 3.75% pesticide solution sprayed on a day when it is 90 degrees F and 36% Relative Humidity. Let’s pretend wind isn’t a factor. Under these conditions, such a droplet will fall 16 inches in the first second. But during that second, evaporation lightens it and it falls a shorter distance in the next second. At the end of 16 seconds it will be 50 microns in diameter, according to this model, and if it is falling at all any more, has slowed to only 3 inches per second. Less than 2 seconds later, it will be 17 microns in diameter and will fall less than one more inch because all the water will have totally evaporated by then. Total distance fallen, 12 feet – maybe. Considering that many if not most of the Gagetown liquid spray applications were conducted from an altitude of 50 feet or more under similar temperature and RH conditions, the potential for a spray drift of toxic pesticides was not only likely, but assured.

In addition to this, consider that a reduction of overall droplet size by 50% in a spray application does not produce twice as many droplets of half the size, but eight times as many, and of a correspondingly much smaller diameter.

At webpage http://www.Geocities.com/capecanaveral/7553/index.htm is a description of the speed and altitude the TBM-3 Avenger applied pesticides. 125 feet above the tree canopy at 150 knots (172 MPH).

Spray drift can be caused by one or more of the following:
(Note: several of these factors act in tandem with one or more other factors to increase or reduce spray drift potential.)

Equipment Factors

- <u>The type of nozzles used, their orientation, orifice diameter, use of a deflector.</u>

Nozzles produce sprays with different droplet size, velocity, trajectory and buoyancy characteristics. Performance depends on the type and design of nozzle, the orifice diameter(s), the spray pressure, nozzle angle, and the application conditions at the time of spray emission, such as sprayer speed, airstream velocity and turbulence. The physical characteristics of the spray mixture are important, especially the surface tension, shear viscosity, extensional viscosity and density. However, nozzle type and application conditions are more important than spray mixture physical properties. Research showing a decrease in droplet size with higher nozzle angle to airstreams has been reported by many scientists including Bouse (1991); Hewitt et al, (1994); Yates et al, (1983) and Kruse et al. Many researchers (e.g. Bouse, 1994) have observed finer sprays with higher liquid pressure for nozzles mounted at angles to an airstream.

Analyses of an early 1970's photograph of the Miramichi, a TBM Avenger aircraft employed to spray New Brunswick, reveals that nozzles were oriented straight downwards (Kelly Franklin 2007)

- <u>Aircraft speed</u>

As airspeed increases from 100 to 160 mph, droplet size is cut in half, but the percentage of spray volume in droplets smaller than 100 microns increases by 4.5 times.

The aircraft used in CFB Gagetown to spray defoliants such as 2,4-D and 2,4,5-T between 1956 – 1964 were TBM Avengers. The Avenger has a cruising speed of about 145 MPH and a top speed of 276 MPH.

In an interview with Frank Gilland, a former TBM Avenger pilot in New Brunswick, Mr. Gilland told me that Avengers flew at 175 knots while spraying. This is 201 miles per hour. January 25 2007, Kelly Franklin.

- Wind shear

Small droplets often result from high spray pressure, small nozzle tips, and wind shear across the nozzles. Shear is especially significant in high-speed aerial applications.

- Boom configuration (shape, number of nozzles, ratio of boom width to wingspan IE boom width should be 70-80% of wingspan or less)

There is a limited amount of space under the aircraft when it is on the ground to mount nozzles. Studies have shown that nozzles mounted low, farther away from the wing and fuselage disturbances, help avoid drift problems. Nozzles should be moved away from the aerodynamic obstruction of other components on the aircraft such as: boom hangars, steps, plumbing fixtures, gear, pumps, and other undercarriage obstructions. Typically, lowering the boom height will reduce drift, but getting too low may increase drift due to the aerodynamic ground effect. Ground effect results when a layer of air is compressed under the wings when heavy aircraft are very close to the ground. This pushes air outward and upward and often will carry spray particles with it.

Helicopters: Spray boom length should be less than rotor length and be consistent with the boom-nozzle system and desired spray pattern.

- Propeller Effects

Determination of off-target drift when aerially applying chemical continues to be a challenge. Meteorological effects, atomization variables, and aircraft design all interact to make this issue a complex problem. In recent years, there has been some interest in the relative effects from either upwind or downwind wings and the direction of propeller wash on spray drift. Propeller wash turbulence carries droplets from nozzles to the right of the fuselage and deposits them beneath or to the left of the fuselage. This results from the clockwise propeller air helix spiraling into the fuselage (Univ. of Nebraska, 2004). Huddleston et al. (1994) performed a test where left and right booms of an aircraft were alternately switched, and drift of malathion and chlorpyrifos were detected using string samplers placed 33- and 91-m downwind. Results suggested that the right boom contributed more to drift than the left boom by the Boom*Position (upwind/downwind) interaction 33-m downwind ($p=0.0251$) There was also significant interaction at the 10% level ($p=0.0968$) at the 91-m sampler distance. Wind speeds ranged from 1.3 to 3.1 m/s throughout the test, but it was not clear whether wind speed or direction were accounted for in the statistical design. A preliminary study conducted by Thomson et al. (2004) found that propeller wash direction and propeller wash interaction with distance were all significant at $p = 0.10$ from fallout sheets used as spray sampling media. There was no corresponding significance using Hi-Vol samplers. The study only considered the weather variables wind speed and direction and did not adjust downwind sampler distances for changing wind direction.

Helicopter: Conventional booms on helicopters produce a large number of fine droplets and mist that are drawn up in whorls off each end of the spray boom. The whorls carry the fine droplets high above the helicopter, where they are most likely to drift with the wind or evaporate and drift away as vapor. Although the swirling vortices increase plant coverage and swath overlap, they also increase spray loss by drift and evaporation.

- <u>Wing-tip vortices and turbulence</u>

Turbulence influences spray drift in various ways. Because individual turbulent motions are random in time, the droplet will move up and down. Plant canopies tend to have very high turbulence intensity both because the canopy elements shed eddies and because mean flows are relatively lower there because they lose energy to friction with the canopy. However, in an unstable atmosphere, strong updrafts may develop as discussed above. These may be capable of transporting droplets to remarkable heights. Spraying in very unstable conditions should be avoided because these large thermal eddies make the spray hard to control.

The final influence of turbulence on drift discussed here is more subtle. When considering droplet evaporation, the droplet can be considered as moving in the flow and the air around the droplet moves with it. The air adjacent to the droplet will thus have a higher humidity in the case of an evaporating water droplet than the free air away from the droplet. This layer of air with properties due to the droplet will slow evaporation. In more turbulent conditions, this boundary layer effect is weakened. Thus turbulence tends to facilitate droplet evaporation.

- <u>Pressure of spray pump</u>

Spray pressure influences the size of droplets formed from the spray solution. The spray solution emerges from the nozzle in a sheet, and droplets form at the edge of the sheet. Increased nozzle pressure causes the sheet to be thinner, and this thinner sheet will break into smaller droplets than from a sheet produced at lower pressure. Also, larger orifice nozzles with high delivery rates produce a thicker sheet of spray solution and larger droplets than smaller nozzles.

- <u>Aircraft/boom height from ground or canopy</u>

The distance a formulation must fall to reach its target, in the absence of other factors, greatly influences the amount of resulting spray drift. In one experiment, a difference of ten feet (raising the boom from an elevation of 10 feet to 20) resulted in five times the percentage of spray drift.

- <u>Droplet spectra</u>

Gravitational forces that act downward on a droplet are opposed by drag forces that act to slow the fall rate. Very small droplets (less than 150 microns or so) fall so slowly because the downward gravitational force is almost equally opposed by drag forces. Atmospheric conditions play a large role in the distance these fugitive airborne droplets can travel.

The physical properties of the tank mix atomized during a spray application can affect the droplet size spectrum, and therefore the drift potential. It should be noted that tank mix physical property effects are not as important as application parameter effects such as nozzle type and use. The active ingredient, formulation type and pesticide type do not affect atomization alone; rather, it is the physical properties of the entire tank mix that affect atomization. A method commonly used in agricultural spray descriptions is the volume median diameter (VMD). This is the droplet diameter that divides the spray cloud into two equal parts by volume – one half of the spray volume being contained in droplets with diameter larger, and one half in droplets with diameter smaller. So there is really a range of size of droplets in any spray application from fine to coarse. A VMD of 300 could mean that half the droplets were 250 microns in diameter and half were 350 microns. Or it could mean half the droplets were 50 microns (very susceptible to drift) and half were 650 microns. The total VMD plus the droplet spectrum gives a more accurate estimate of the droplet size relative to drift. Droplets under 150 – 200 microns in diameter are the most drift-prone under most application conditions.

As airspeed increases from 100 to 160 mph, droplet size is cut in half due to wind shear, but the percentage of spray volume in droplets smaller than 100 µm (100 microns) increases by 4.5 times. This could be the reason that higher speed aircraft are cited for drift claims more often than are lower speed aircraft. If an aerial applicator decided to increase airspeed from 130 to 160 mph without changing spray nozzle setup, the highly driftable small droplet content of the spray would increase three times.

Formulation Factors

- <u>Viscosity of formulation</u> (Extensional, shear and dynamic surface viscosity)

Several physical properties of the droplet liquid, such as surface tension and extensional viscosity, may affect reflective potential of spray droplet from plant leaves. Equilibrium surface tension, a commonly measured liquid property, is not a reliable indicator of reflection tendency. However, dynamic surface tension has been found to be strongly related to droplet reflection. An oscillating jet method was developed enabling measurement of dynamic surface tension at a range of short surface ages, even as short as 1 ms. Bohr's equation and Bechtel's inverse method were used to calculate surface tension from measurements of the jet waveforms. Some surfactants are unable to reduce surface tension rapidly at short air-liquid interface ages typical of droplet impaction processes. Hence, they may be unable to effectively limit reflection and improve retention. A thin-film diffusion model was developed which can be used to calculate dynamic surface tension at a range of surface ages, given liquid properties, surfactant diffusivity, apparent interfacial film thickness, and surfactant concentration. Correlating measured dynamic surface tension data with the diffusion model provides estimates of apparent film thickness and diffusion of surfactant/water mixtures. These activity properties are useful in understanding surfactant effects on high shear rate physical processes such as droplet atomization and leaf-surface impact, where short surface ages are critical. Most agricultural sprays are mixtures of materials, not true solutions, and as such their surface tensions change with surface age. Measuring surface tensions at short surface times may also be valuable in predicting droplet size spectra from atomization processes, because these processes are usually completed in less than 3 ms. Brazee et al. (1991), Bechtel et al. (1995), Reichard et al. (1997)

- Vapour pressure/volatility of formulation

Some volatile chemicals will change phase and disperse as a gas while others are non-volatile and will not. Deposited material may, under some circumstances, reenter the atmosphere. This is known as secondary drift.

All herbicides can drift as spray droplets, but some herbicides are sufficiently volatile to cause plant injury from drift of vapor (fumes). For example, 2,4-D or MCPA esters may produce damaging vapors, while 2,4-D or MCPA amines are essentially non-volatile and can drift only as droplets or dry particles.

Vapor drift occurs when a volatile herbicide changes from solid or liquid into a gaseous state and moves from the target area. Herbicide vapor may drift farther and over a longer time than spray droplets. However, spray droplets can move over two miles under certain environmental conditions so crop injury a long distance from the intended target is not necessarily due to vapor drift. A wind blowing away from a susceptible crop during application will prevent damage from droplet drift, but a later wind shift could move damaging vapors from the treated field into the susceptible crop. An experiment conducted in Canada demonstrated that 3 to 4 percent of both 2,4-D amine and high volatile ester drifted out of the target area as spray droplets. However an additional 25 to 30 percent of the ester drifted as vapor in the first 30 minutes after spraying while no additional movement of the amine was detected.

- Additives to formulation (called adjuvants, diluents, emulsifiers, surfactants)

Additives can affect the droplet size and the rate of evaporation. Both of these can affect the amount of spray drift. Materials such as the organosilicones, for example, are used as penetrants, spreaders, and wetters. In this capacity they typically cause a significant reduction in surface tension of the spray mixture which is, at least partly, responsible for drop size distributions which have greater volume of the spray in small (<200µm) droplets. These small drop sizes are, of course, more drift prone and thus greater attention must be paid to application parameters such as hardware and operating conditions when using these adjuvant types.

Meteorological Factors

- Temperature inversion

Under temperature inversion conditions the temperature increases as you move upward. This prevents air from mixing with the air above it. This causes small suspended droplets to form a concentrated cloud that can move in unpredictable directions for long distances. If large numbers of small droplets are captured in this warm or inversion layer, the deposition control is lost. Records indicate that movement of these inversion layers may transport chemicals for several miles.

- Relative humidity

The importance of relative humidity to spray drift derives from the dependence of spray drift on droplet size. After release into the atmosphere, the initial droplet size begins to shift towards smaller sizes. The rate of change of droplet sizes over the entire droplet size spectrum depends on the chemistry of the released material and the humidity of the air. Assume the spray droplets are spherical. The volume (and thus the mass of a uniformly mixed drop) varies with the cube of the sphere diameter. A water droplet of 200 microns diameter has a settling velocity of 0.705 meters per second while a droplet of 40 microns has a settling velocity of 0.047 meters per second. This is a factor of five difference in droplet diameter and a factor of 15 difference in settling velocity. Consider a release height of 15 meters and a wind speed of 1 meter per second. If we ignore the effects of turbulence and assume for simplicity sake (unrealistically) that the wind is laminar, a droplet of 200 microns diameter would move with the wind 21 meters before reaching the surface while a droplet of 40 microns would move 318 meters. It must be emphasized that this is an overly simplistic portrayal of droplet movement in the atmosphere. The point is that as the droplet evaporates, the location that the droplet impacts the surface is greatly altered and prediction of that point of impact becomes increasingly difficult.

Low relative humidity and/or high temperature will cause more rapid evaporation of spray droplets between the spray nozzle and the target than will high relative humidity and/or low temperature. Evaporation reduces droplet size, which in turn increases the potential drift of spray droplets. For example, very fine particles can drift 367 yards to a few miles with only a 3 miles per hour wind (Table 1). However, low humidity may reduce the phytotoxicity of the herbicide because rapid drying of a spray droplet will reduce herbicide penetration into a plant. Also, plants growing in low humidity produce a thicker cuticle than in high humidity, resulting in greater resistance to herbicide penetration. In general, total drift movement of herbicide out of the target area will be greater with low relative humidity and high temperatures. However, the influence of humidity and temperature on plant injury from herbicide spray drift is not entirely predictable. In some cases plant injury from drift may be increased by low relative humidity and high temperature while in other cases plant injury from drift may be greater with high relative humidity and low temperature.

Temperature also influences the volatility of herbicides. Research results indicate that vapor formation from a high volatile ester of 2,4-D approximately tripled with a temperature increase from 60 to 80 degrees Fahrenheit (8). At 80 F, 2,4-D vapor formation was about 24 times greater from a high volatile than a low volatile ester.

Vapor damage to tomato plants from various formulations of 2,4-D at different temperatures showed vapors from high volatile esters caused injury to plants at all tested temperatures (Table 2). The low volatile esters of 2,4-D did not damage plants at 70 to 75 F but did at 90 and 120 F. Even though low volatile esters of 2,4-D are much less volatile than high volatile esters, vapor drift from low volatile esters can damage susceptible plants. The amine formulation was essentially non-volatile, as no damage-causing vapor was produced even at high temperatures.

These results indicate that a low volatile ester would begin to release damaging vapors at a temperature between 75 and 90 F. However, soil surface temperatures are often much warmer than air temperatures, especially on a sunny day. Thus, vapor drift from low volatile esters may occur at air temperatures lower than 75 F.

- Solar radiation

The sun produces short waves of energy that easily pass though the atmosphere with little effect. The ground absorbs these waves and re-emits them as longer waves of energy which are readily absorbed by the atmosphere. Thus, the air is heated from below on a hot day, not from above.

Another factor is that warm air is not as dense as cold air and is therefore lighter. When the surface of the Earth is heated, during a sunny afternoon for instance, the air near the surface wants to rise through the colder air over it. This is known as an unstable surface layer or temperature inversion and will generally not occur if there is a strong wind or thick cloud cover. In an unstable situation, a parcel of air can become lighter than the air above it and heavier than the air below it. Therefore, if the parcel is moved up or down it will keep moving away from its point of origin. A small perturbation can result in substantial mixing, and is characterized by large 'bubbles' of air lifting off the surface. These are the thermals that aviators are familiar with. This type of motion can result in cumulus formation (even initiating cumulonimbus or thunderhead formation). Near the surface, the liftoff of some air causes other air to rush in to replace it, resulting in the intermittent winds of variable direction characteristic of many summer afternoons.

- Wind

Wind speeds measured on the surface are much less than at an altitude of 70 feet. The increase of wind speed with height is approximated as logarithmic.

Dead calm conditions are never recommended because of the likelihood of temperature inversions.

Applications should not be made when wind speed exceeds 10 mph. Be cautious when applying in wind speeds less than 2 mph because temperature inversions may be present and wind directions may vary.

- Atmospheric stability/Thermoclines/Temperature inversions

Horizontal air movement (wind) is generally recognized as an important factor affecting drift, but vertical air movement often is overlooked. Normally, air near the soil surface is warmer than higher air. Warm air will rise while cooler air will sink which provides vertical mixing of air. Small spray droplets suspended in the warm air near the soil surface will be carried aloft and away from susceptible plants by the vertical air movement. Vertically stable air (temperature inversion) occurs when air near the soil surface is cooler or similar in temperature to higher air. Small spray droplets can be suspended in stable air, move laterally in a light wind and impact plants two miles or more downwind. Vertically stable air is most common near sunrise and generally is associated with low wind and clear skies. Three times more spray was detected 100 to 200 feet downwind and 10 times more was detected 1,000 to 2,000 feet downwind with vertically stable air as compared to normal conditions with a given wind speed.

Spray drift in vertically stable air can be reduced by increasing spray droplet size. Herbicides should not be applied near susceptible crops when vertically stable air conditions are present. Vertically stable air can often be identified by observing smoke bombs or dust from a gravel road. Also, fog is an indication of vertically stable air and dew formation generally indicates vertically stable air.

Topographical Factors

- Height and density of canopy (% open or closed at crown)

Canopies are usually moister (higher humidity) than open areas. Wind speeds tend to be lower due to drag by the canopy elements. Turbulent intensity tends to be higher because of eddy shedding off of canopy elements. The canopy intercepts solar radiation. Under closed canopies, a stable layer (inversion) can exist in the middle of the day due to shading.

Another factor leading to spray drift in the Gagetown situation would be the decrease in spray-stopping foliage as the years passed. A spray application would encounter little hindrance from the denuded branches of a previously treated tree. This can be compared to the spraying of dormant orchard trees. Many fruit trees are sprayed when the trees are dormant. One researcher measured leaf area indices (LAI) of about 3 for semi-dwarf trees with foliage and about 0.6 for dormant trees. Thus there was a much smaller target for spray during dormant applications. This was shown by Herrington et al (1981). They found that only about 10% of applied spray was deposited on the tree parts during dormant application. The SDTF (1998) also found that spraying dormant trees resulted in greatly increased downwind deposits compared to spraying trees in full foliage.

- Channeling of wind in valleys, along contours/Updrafts from cliffs, hills

In 1988, Margaret Hue of south-central Washington State discovered spray drift from paraquat applications was landing on her property. These applications were being made on upland wheat fields, drifting down through steep canyons, and spreading out on the irrigated orchards and fields and the towns below. At first, the wheat farmers claimed it was impossible for their paraquat to drift in a northerly direction. After all, they had tested the ground wind direction prior to spraying and the breezes were coming from the northeast. However, the winds several hundred feet above the surface were flowing stronger and from the southwest. As droplets of paraquat moved up into these winds aloft, they were transported north and east, eventually mixing and dropping into the air that worked its way down Badger Canyon and across the Tri-Cities. The paraquat had drifted against the wind, causing spotting on vegetation up to 15 miles away. All in all, Washington state agriculture officials received 141 complaints and documented 100 square miles of paraquat drift. (Glantz, 1989)

Human Factors (Sprayer/Pilot)

- Ignorance, lack of training

Training should be conducted on a regular basis for all spray program participants. Better training for newer, more complicated spray technology.

How common is spray drift?

In the USA, some organic farmers cannot produce products without residues due to inadvertent environmental contamination such as drift from a neighboring farm. They have adopted the concept of unavoidable residual environmental contamination (UREC) for residues that occur from inadvertent, uncontrollable sources. Most organic produce does not contain detectable pesticide residues. The purpose of organic pesticide residue standards and UREC's has been to address the practical limitations of producing organic food in an increasingly polluted world.

On the USA's Environmental Protection Agency's website, under the title Spray Drift of Pesticides, sub-heading: How Does EPA View Off-Target Spray Drift? is the following statement:

"When labels of pesticide products state that off-target drift is to be avoided or prohibited, our policy is straightforward: pesticide drift from the target site is to be prevented. However, we recognize that some degree of drift of spray particles will occur from nearly all applications."

Few of the reviewed reports would commit to a figure for the amount of spray drift produced per typical aerial spray application. Those who provided percentages are:

- Robert D. Fox, Richard C. Derksen and Ross D. Brazee, USDA-Agricultural Research Service, Wooster, Ohio in *Air-Blast/Air-Assisted Application Equipment and Drift* (1998) "…it appears that about 30% of applied spray is still unaccounted for."
- Siegfried and Holliger (1996) stated that about 40-50% of spray was deposited on the leaves and fruit, about 20% on the ground and about 20% lost as drift.
- Robert E. Wolf, University of Illinois, Urbana, Illinois (1998) in *Boom Application Equipment and Drift (see chart below):*

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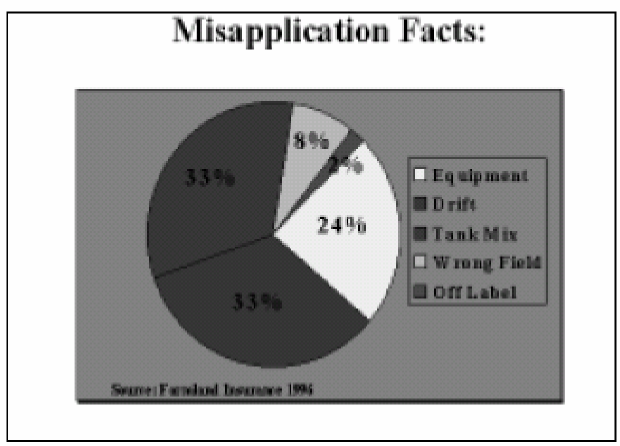
This chart categorizes and shows the breakdown of the factors related to misapplication. The source is a major agricultural insurance agency and it is based on their investigations and payouts in 1996. Thirty-three percent of the time the misapplication was due to drift. Another 33% of the time it was due to an improper tank mix. The application equipment was the source of the misapplication 24% of the time. Applications to the wrong field or site were the cause of 8% of the misapplications. Off-label applications were only responsible for 2% of the misapplications.



This author's second chart (not shown) shows the breakdown of factors that contribute to pesticide drift. Thirty-eight percent of the time the applicator, or the decisions made by the applicator, are responsible for pesticide drift. The type of nozzle or nozzle problems are responsible 26% of the time. Physical effects such as wind, inversions are responsible 23% of the time. Other factors that are unknown resulted in drift 13% of the time. Many times the source or cause of a complaint is hard to isolate if several applications take place in the nearby area.

- In 1993, the National Research Council of the National Academy of Sciences characterized drift as "considerable" because it ranges from about 5 percent under optimal, low-wind conditions to 60 percent under more typical conditions. (National Research Council, 1993)
- The Congressional Office of Technology Assessment estimates that about 40 percent of an aerial insecticide application leaves the "target area" and that less than one percent actually reaches the target pest. (US Congress, 1990)
- “Two years ago, our staff reviewed 16 studies about aerial drift (virtually all the studies available to us) and found that in each study there were pesticides detected as far away from the application as samples were taken.” (Cox, 1995) The drift in these studies ranged from 100 to 1600 meters. Drift happens whenever pesticides are sprayed. The US EPA estimates that about three fourths of the one billion pounds of conventional pesticide active ingredients used in 1995 were applied on America's food crops. (Aspelin, 1997) That is a lot of pesticide. Drift problems will stop only when we stop spraying pesticides, not when we spray better. Norma Grier, Northwest Coalition for Alternatives to Pesticides Eugene, Oregon (1998)
- The pesticide delivery process, hereinafter referred to as pesticide dose transfer, is generally regarded as highly inefficient. For insecticides typically < 1% reaches the target organism (Graham-Bryce, 1983), and uptake efficiency of most pesticides is considered to be around 20%. Much of the wasted material contributes to environmental and/or operator contamination and also represents a significant material loss to the end user. Chemistry and Drift Management: A Biologist’s Perspective, Roger A. Downer & Franklin R. Hall, The Ohio State University, Wooster, Ohio (1998)
- According to Farmland Insurance’s loss statistics for 1997, pesticides were misapplied to 35,000,000 acres and they had to pay out almost $5,000,000. The breakdown was: 47% Wrong product/Incorrect amount (mistook quarts for pints etc); 32 % were for Inadequate rinsing/Improper calibration; 11% Drift; 8% Wrong field. 1996 was an even worse year.
- When spraying cuttings on rough, mountainous terrain, flying height must often be 50 feet or more above the vegetation; it may exceed 100 feet where flight lines are obstructed by snags or tall trees. In such areas, drift and evaporation may result in loss of more than half the active ingredients when applying phenoxy herbicides. Approximately 60 to 75 percent of low volatile esters .of 2,4,5-T in diesel oil were lost from an early spring aerial application in the Oregon Coast Ranges (Norris 1967). To reduce drift and evaporation and to insure pilot safety, all dead trees and weed trees more than 10 feet tall should be felled during logging. USDA forest service general technical report pnw-14 (1974) H. Gratkowski

Conclusions

Other very disturbing information regarding pesticide application has been revealed in the course of this research. These are:

- Leather, if impregnated with pesticides, cannot be decontaminated. A significant proportion of a soldier's gear consists of leather; shoes, cases, belts and harnesses. This point brings into question the role played in contaminating other people, who were not directly exposed as soldiers were, by leather and other materials used by personnel in the field such as canvas, wool and wood.
- There may be no way to know if you have been contaminated by a spray drift.
- Some pathogens existing in ponds providing water for pesticide dilution have shown the ability to survive such admixture and are subsequently sprayed with the formulation.

It is suggested that an over-arching paper be produced to cover all the pathways of pesticide transportation which would include spray drift, which is only one conduit of such dissemination. The other pathways are:

- Transportation by water such as runoff and seepage into aquifers.
- Erosion by wind as windblown particles of organic material as dust.
- Atomization due to subsequent burning of herbicide-created debris.
- Precipitation of suspended atmospheric pesticides in the form of rain.
- Biologically transported methods as with fish and waterfowl.

AVENGER INFORMATION

Specifications of the Avenger aircraft:
Number manufactured: 9,836 (32 versions, many were conversions)
Number of Grumman TBF-1C manufactured: 764
Number of Grumman TBF-1 manufactured: 1,524
Number of Grumman TBF-1B manufactured: 402
Number of General Motors TBM-1 manufactured: 550
Number of General Motors TBM-1C manufactured: 2,332
Number of General Motors TBM-3 manufactured: 4,657

One engine (single propeller)
Length: 40 feet
Wingspan: 54 feet 2 inches
Wing area: 490 square feet
Wing aspect ratio: 4.99
Height: 16 feet 5 inches
Empty weight: 10,545 pounds

Maximum weight: 17,985 pounds
Maximum speed: 257 MPH at 12,000 feet; 276 MPH
Cruising speed: 147 – 160 MPH
Service ceiling: 21,400 feet
Ceiling: 30,100 feet
Ferry Range: 1,010 miles
Normal crew: 3

Record of crashes in New Brunswick:
May 20, 1975 – full load of insecticide

"Tanker 20" CF-ZYC crashed in the evening shortly after takeoff from Juniper Airstrip. Single pilot was only crew and he was only slightly injured.

This article also notes crashes in 1998 (Tanker 14) and 1999 (Tanker 17) but no other details.

http://acam.ednet.ns.ca/avenger/avenger.htm

The crash of a TBM Avenger (C-FAXS, Tanker B17) in June 1979 is described at:
http://www.Geocities.com/capecanaveral/7553/billyof.htm
This occurred during a spray operation near Sevogle, NB.

The crash of a TBM Avenger (Tanker 20, C-GLEH) June 6 1987 is described at:
http://www.Geocities.com/capecanaveral/7553/billyof.htm
This occurred at 6:15 AM at Boston Brook. The aircraft is described as being ¼ full of insecticide.

The crash of a TBM Avenger (Tanker 19) May 1983 is described at:
http://www.Geocities.com/capecanaveral/7553/popourr.htm
This occurred at Sevogle during a test flight (presume no insecticide.)
The crash of a TBM-3E Avenger (Bu. #85836) June 10 1984 is described at:
http://www.Geocities.com/capecanaveral/7553/crash.htm
This occurred at 5:30 AM after departing Brockway Airstrip. The pilot hit a "tall" tree while lining up for a spray run but I'm unsure this confirms that spraying was done just above treetop level. The pilot describes insecticide leaking from his crashed aircraft. Aircraft insecticide tank was probably nearly full.

The crash of a TBM Avenger (Tanker 7) 1984 is described at:
http://www.Geocities.com/capecanaveral/7553/popourr.htm
This occurred at Charlo at takeoff (presume full of insecticide) but, seeing as the accident took place on the runway, the tank may have remained intact.

Forest Protection Limited

From their site: “In 1953, Forest Protection Limited completed 8,000 aircraft sorties in a single 35 day operation.”

From: "Mare" <marilynndoherty@...>
Date: Wed Jan 24, 2007 7:40 pm
Subject: Re: Avengers maredisland
Offline
Send Email
Invite to Yahoo! 360°

Kelly, I received an email from Suzanne McCann a few days ago about the spray planes. She lived in Enniskillen at the time and this community was one of the worst affected by the spraying. I'll copy what she said below. She's a wealth of information: Mare

From Suzanne:

Here's what I know for sure re: the spraying, The contract companies used fixed wing aircraft until the defoliant drift that killed the crops across the river, Maugerville, Burton etc. area's. They loaded these planes at the old Blissville airport then when the drift happened, they switched to helicopter to spray, and they loaded them in Enniskillen on the Keegan road that was in 1973-74.

They must have also loaded helicopters up by the Base area by the Shirley road. There is no air strip handy there so I assume it had to be helicopters. They could land a light plane out in Petersville because one crashed there (Not spraying) and the pilot was killed. There is a monument out there but I see they have moved it over by the Petersville commissionaire bldg.

One of the fixed wing air planes crashed while we were watching them spray Lloyd went in and helped the pilot out of the plane and he dumped his load right where he went down. He was not hurt, then our next door neighbour went out with his tractor and hauled it out to the Enniskillille road. I am not sure of the exact year but it was between 1966--1969.

The old avenger air planes were all parked at the Blissville airport they used them mostly for budworm and we could sit on out front steps and see the spray coming out of the planes. They did all the wooded area around Hoyt, Wirral, Clarendon, Enniskillen. They probably did use them for the other chemical too, I'm not sure they were Gov. planes then.

Talk about a roar when those planes went overhead, When they took off from the Blissville airport they had to fly straight over the Enniskillen houses. That is the direction of the runway.

Hope this is some help

THE EFFECT OF LOAD AND AIR TEMPERATURE ON AERIAL APPLICATION GROUND SPEED

ASAE Paper No. AA02-003

Author: Lowrey Smith

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Summary: Most aerial applicators will agree that a **spray plane flies more slowly when fully loaded than when empty** with the same engine power and RPM settings. However, the magnitude of this difference has not been well documented and is affected by various environmental factors. A study was performed to determine if the ground speed changes due to load changes were sufficient to have a significant effect on the application rate of granular materials. An Air Tractor 402b (turbine-powered), equipped with a SATLOC swath guidance system and an AutoCal Automatic Flow-Controller was used to collect the required data. Data logs from the SATLOC system provided ground speed and spray-time data and AutoCal data files provided flowrate data from each spray run. Test protocols were developed to minimize effects of parameters other than load on ground speed. The plane was loaded with 275 gal of water for each test to simulate the approximate weight of a fertilizer load. Results indicated that ground speed increased as load decreased and that increased air-temperature tended to magnify this change.