U.S. EPA Approach to Spray Drift Management

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US EPA Goal for Spray Drift Management

- Ensure growers have pesticides that can be used without causing unreasonable adverse effects on human health and the environment from spray drift.
- Consideration of risks, benefits, social factors

US EPA's Approach to Addressing Pesticide Spray Drift

- Use high quality science to estimate potential risks from a pesticide's uses.
- Ensure drift reduction requirements are based on this science and are practical, flexible, and enforceable to achieve drift reduction.
- Encourage development and use of drift reduction technologies.
- Support drift reduction education for applicators.

US EPA Pesticide Licensing: *FIFRA requires:*

- Scientific studies to define a pesticide's potential toxicities and exposures from labeled uses;
- Appropriate label directions and risk management measures to protect health and the environment;
- Pesticide and its uses "without causing unreasonable adverse effects on the environment" when
    - "performing its intended function" (according to the label) and
    - "used in accordance with widespread and commonly recognized practice."

Advancing the Science of Risk Assessments

- EPA estimates a pesticide's risks from its chemistry, toxicities, uses, and routes of exposure – spray drift is one route.
    - Humans and non-target terrestrial and aquatic animal and plant species, including endangered species
- EPA is improving its science assessment methods with more precise estimates of exposures and risks.

How Is EPA Improving Its Drift Estimates and Risk Assessments?

1) Development of an improved ground boom spray drift model:
    - Most ground boom spray drift estimates are based on field trial data (e.g., AgDRIFT);
    - The mechanistic aerial model has been modified for modeling ground boom applications;
    - The mechanistic ground boom model is undergoing evaluation
        - Milt Teske (Continuum Dynamics, Inc.) presentation on Friday.

How Is EPA Improving Its Drift Estimates and Risk Assessments?

2) EPA is improving regional spray drift estimates for aquatic assessments.
    - The AGDISP model is being linked with runoff and aquatic fate models
3) AGDISP is being enhanced to read site-specific weather files.
    - 30-years of measurements at hundreds of US sites

How Is EPA Improving Its Drift Estimates and Risk Assessments?

4) Linked runoff and spray drift models will provide site specific estimates of spray drift levels with return frequencies.
5) EPA is changing from deterministic to more sophisticated probabilistic risk assessments.

- These changes will lead to more precise assessments and risk management decisions.

Drift Management for Applicators

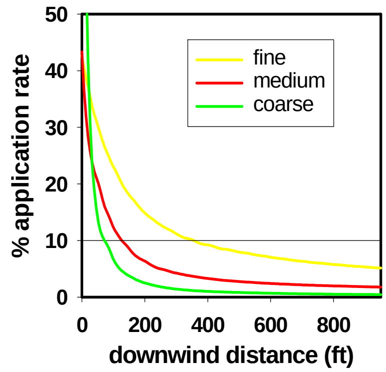
- EPA is improving development of drift management decisions for pesticides.
    - Specific to each pesticide;
    - Based on more precise estimates of risks;
    - Based on the pesticide's risks and uses;
    - Input from manufacturers, growers, and others.

Drift Management for Applicators

This regulatory approach results in:

- Drift management commensurate with a pesticide's risks
    - Low risks = no/few measures
    - High risks = significant measures
        - E.g., pesticide with fish LC50 of <1 ppb
- More flexible approaches for applicators and growers
- Protective and enforceable measures

Managing the Drift-Hazard Curve



Options for Drift Management

- EPA collaborates with a pesticide's manufacturer, users, and others on drift management options.
- Spray method and equipment
- Droplet size
- Application/release height
- Buffer zones (infrequently required)
- Requirements vs advisories

Encouraging Use of Drift Reducing Technologies

- EPA is collaborating with manufacturers and others to encourage development and use of drift reducing technologies.
- DRTs can provide applicators with more options for reducing drift.
- Potential option to more stringent drift management measures
- E.g., use DRT rather than a buffer zone
- Greg Sayles (EPA) presentation on Thursday

Drift Education

- EPA is supporting drift education of pesticide applicators.
- Funding and training material for aerial applicator annual program
    - Professional Aerial Applicators Support Systems classroom and fly-in programs
- Funding for government required training for pesticide applicators
    - Certification and Training Program

In Summary…EPA is improving its scientific and regulatory decisions on spray drift by:

- Advancing scientific methods and models for more precise risk estimates;
- Developing science based and more flexible drift management measures for labels;
- Promoting drift reduction technologies;
- Supporting applicator education and training.

Invited Presentation Articles

Canadian Regulatory Goals and Proposed Approach to Buffer Zones

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Abstract

The approach outlined in this document is a concept that is being considered by the Pest Management Regulatory Agency (PMRA), Health Canada, and will involve consultation with all stakeholders, which may result in modification of this approach. The toxicity of a pesticide to non-target organisms is an inherent property of the pesticide's active ingredient and is used by the PMRA to establish pesticide-specific buffer zones. As agricultural pesticides are applied across Canada under a wide range of conditions, there is a need to refine the way in which buffer zones are determined to reflect the variability between sensitive habitats, operational configurations (i.e., meteorological conditions and sprayer configurations), and advances in application technology. This document outlines a proposed strategy for a new flexible approach to modify pesticide-specific buffer zones for agricultural applications of pesticides. This approach will allow applicators to modify the labelled pesticide-specific buffer zones by a site-specific multiplier based on the characteristics of the sensitive aquatic habitat, the application equipment and meteorological conditions. In this manner, the observed buffer zone will be pesticide-, site-, and operationally-specific. It is believed that the proposed approach is 'risk neutral'; that is, it will provide the PMRA and the applicator with considerably more flexibility than is presently allowed without increasing risk to the environment.

Introduction

During and after application, a pesticide can move through the environment by several routes, such as spray drift (particle and vapour), runoff, and leaching. Each transportation process presents different problems to sensitive areas and each may require mitigating measures to minimise the adverse effects of the pesticide on these environments. Particle (droplet) spray drift is defined as the wind-induced movement of spray particles (droplets) away from the spray swath during application. This definition does not include post-application vapour drift and for the purposes of this document, the term 'spray drift' will refer only to particle drift. In addition, this document does not consider: the effects of post-application runoff and leaching; forestry pesticide applications, as these applications are complex and very different from agricultural applications; or buffer zones for non-target crops.

During the review process, the Pest Management Regulatory Agency (PMRA) evaluates the risks to non-target organisms posed by the use of a pesticide. In the environmental risk assessment, the environmental toxicity of the pesticide's active ingredient is assessed, and aquatic or terrestrial organisms that are sensitive to the compound are identified. If a risk is identified, then various strategies are implemented to reduce this risk, one of which may be the requirement for a buffer zone during application. A buffer zone is defined as the distance between the point of direct pesticide application, usually the end of the spray swath, and the nearest downwind boundary of a sensitive area. A 'sensitive area', in the context of this document, is defined as an area containing or comprised of organisms that are sensitive to the pesticide being applied. A sensitive area may be aquatic (including permanent and non-permanent water bodies), terrestrial (e.g., shelterbelts and woodlots), or a combination of both (e.g., wetlands, riparian zones, wet meadows, marshes, swamps, fens, and bogs).

The PMRA is using models or empirical data to calculate pesticide-specific buffer zones, in which the basic underlying principle is: the more risk the pesticide is to a sensitive non-target organism, the larger the buffer zone. The PMRA also believed that refinements to the calculation of buffer zones were needed in order to reflect the variability between sensitive areas, differing application practices, and advances in application technology.

This document outlines a proposed strategy and its rationale for a new flexible approach for implementing buffer zones for agricultural applications of pesticides. In developing this approach, the PMRA considered that an increased awareness of environmental buffer zones could potentially have negative results. The buffer zones could be disregarded by applicators who see them as impractical and unenforceable by the PMRA. Destruction of wildlife habitat may be seen as an option to avoid buffer zones if they are seen to impede efficient agricultural production. Finally, imposition of limitations on agricultural practice may be viewed as negative by a farming community that already feels under attack by economic forces and views governments as ineffective at addressing its most urgent needs. As a result, the PMRA attempted to develop an approach that is practical and transparent, and that should not result in undesirable effects, i.e., unintended outcomes which would work against the very goal of protecting the environment.

This document does not consider the issue of human health risks and spray drift. At the present time there are insufficient data or standardized methodologies available to quantify either direct or indirect human exposure originating from spray drift. The PMRA and the US EPA are currently developing methodologies that will help quantify such potential exposure (e.g., *Overview of Issues Related to the Standard Operating Procedures for Residential Risk Assessments* (August 1999)). For human health assessments, the PMRA does, however, conduct exposure and risk assessments that are pesticide-specific and that take into account each potentially exposed population including: general population, pesticide applicators, agricultural workers and others who re-enter treated areas after application and who may be exposed to pesticide residues. The potential for direct or indirect bystander exposure from spray drift is specifically addressed through a qualitative assessment. Other types of exposure, such as via food and drinking water, are addressed by quantitative assessments.

Objectives

The objectives of the strategy presented in this document are: to develop an approach for determining site-specific buffer zones for agricultural applications of pesticides that protect habitats, but are also flexible enough to meet the needs of growers and applicators; to encourage applicators to use new technology and sprayer configurations to reduce spray drift; to increase awareness of the effects of meteorological conditions on spray drift and to encourage applicators to spray only under favourable conditions; to increase awareness of the appropriate buffer zones to use when preparing a spray program; and to make the process simple and easy for applicators to use.

The PMRA examined various options with respect to the characteristics of sensitive areas to be protected, the meteorological conditions under which the spray is applied, and the configuration of the spray equipment used to apply the pesticide. It is believed that the proposed policy is 'risk neutral', i.e., it will provide the PMRA and the applicator with considerably more flexibility than is presently allowed <u>without increasing risk to sensitive environmental areas</u>.

The mechanics of buffer zone modification are complex. The proposed approach, however, allows the applicator to understand the process quickly, to gather the required site-specific information before the spray application, to select an appropriate buffer zone modifier from tables and to apply a multiplier to the labelled buffer zones. The emphasis is to develop a relatively simple process for a quick and effective determination of a buffer zone, but one based on sound science to ensure the protection of sensitive areas. It is recognized that increased flexibility means increased responsibility for the applicator to gather the required information and, if necessary, to perform the proper calculations. Consequently, an important component of this initiative is the involvement of federal and provincial authorities, and other stakeholders to educate applicators about this new approach. Revised product label statements will be developed to draw attention to the new buffer zone requirements.

Current PMRA Methods for Buffer Zone Determination

To support the registration of a pesticide in Canada, the registrant must submit information describing the chemistry, environmental fate, human and environmental toxicity and efficacy of the pesticide, and its use pattern. The need for buffer zones arise as a result of the risk assessment from the review of the environmental fate and toxicity information. The environmental risk posed by a pesticide is a function of the pesticide's toxicity to non-target organisms and the level of exposure of these organisms to the pesticide. The integration of these two factors, toxicity and exposure, provides an indication of the level of concern for non-target organisms in the environment and whether risk mitigation (e.g., a buffer zone) will be needed.

The toxicity of a pesticide product to non-target organisms is primarily due to the active ingredient(s) (a.i.). This toxicity is expressed as a dose-response relationship between the concentration of the active ingredient and the adverse effects upon the organism, such that increased concentrations of (exposure to) the compound results in increased adverse effects. Adverse effects may be lethal or sub-lethal (e.g., changes in behaviour, changes in reproductive success). Currently, the PMRA uses the NOEC (No Observable Effect Concentration) for fish, *Daphnia* sp., algae or *Lemna* sp. (aquatic organisms) and the EC_{25} (a 25% inhibitory effect in a measurement parameter such as seed germination, seedling emergence, plant height, plant dry weight, shoot length, shoot weight or root weight) for terrestrial plants as the endpoints of concern in its risk assessments. In either case, terrestrial or aquatic, the appropriate endpoint of the most sensitive non-target organism is used for the purpose of calculating a buffer zone.

The level of exposure of non-target organisms to a pesticide is estimated through the calculation of an Expected Environmental Concentration (EEC) of the pesticide. For terrestrial plants, the EEC is expressed in terms of the application rate of the active ingredient (g a.i./ha). For aquatic organisms, the EEC is the concentration of the active ingredient in a water (g a.i./L). The EEC in water is a determined by calculating the concentration of the pesticide in a field-side pond with a surface area of 1 ha (100 m x 100 m) and a depth of 30 cm. In both cases, the calculations are based on the maximum application rate. If multiple applications of the pesticide are allowed, then the EEC is calculated by considering the maximum single application rate times the maximum number of applications, factoring in the dissipation characteristics of the pesticide, i.e., the half-life or time for 50% of the pesticide to disappear, between applications.

Off-site spray drift and deposition is largely independent of the physical/chemical characteristics of an active ingredient, but may be dependent on the physical/chemical characteristics of a formulation; however, no information is provide to the PMRA on the drift reducing capabilities of the formulation ingredients in the pesticide product. The PMRA uses various information sources to determine the amount of off-site drift for various methods of application. For field sprayer applications, i.e., typically ground rigs pulled behind a tractor or high boom clearance sprayers, the empirical data of Wolf and

Caldwell (2001) are used to estimate downwind deposition. For airblast applications, data from Ganzelmeier *et al.* (1995) are used. For chemigation, basic application is assumed to be a high pressure, impact sprinkler, not equipped with an end gun, with a height of 3.5 m. Due to the lack of a suitable drift data for chemigation, the Wolf and Caldwell (2001) data are used. The rationale for this is that, even though the droplets are much larger for chemigation, the higher boom height increases the drift potential and these factors roughly compensate for one another. These drift data were used to construct mathematical functions that describe the deposition of a pesticide over distance. For aerial applications, the AGDISP model (Teske *et al.* 2003) is used to describe deposition.

Buffer zones for aquatic habitats are calculated by using the aquatic EEC and the NOEC for the most sensitive aquatic organism as input values to the function that describes the deposition of the pesticide over distance. This function is used to determine the appropriate distance, i.e., the buffer zone, in metres that the spray equipment should be from the sensitive aquatic habitat when the pesticide is applied. It should be noted that buffer zones are used when a sensitive aquatic habitat is downwind of the spray swath.

Terrestrial buffer zones are calculated by using the terrestrial EEC and the EC_{25} for the most sensitive terrestrial plant as input values to the function that describes the deposition of the pesticide over distance. This function is used to determine the appropriate distance, i.e., the buffer zone, in metres that the spray equipment should be from the sensitive terrestrial habitat when the pesticide is applied. As for aquatic habitats, buffer zones are used when a sensitive terrestrial habitat is downwind of the spray swath.

The buffer zones calculated through the use of these functions or the AGDISP model are specified on the pesticide label. The PMRA believes that the use of conservative drift scenarios and the NOEC or EC_{25} of the most sensitive species results in buffer zones which are upper bound estimates of those required to protect non-target organisms.

By combining information on the amount of drift and exposure with appropriate data on toxicity, it is possible to determine if drift during application is likely to cause adverse effects on non-target organisms. If a risk is identified, i.e., if the EEC is greater than the NOEC or EC_{25} of the most sensitive non-target organism, it is then possible to determine what reduction in drift would be required to reduce the risk to an acceptable level, i.e., the EEC equal to or less than the NOEC or EC_{25} of the most sensitive organism. Assuming that the application rate remains unchanged, a reduction in drift to sensitive areas can be achieved by: (a) implementing a buffer zone; (b) spraying under more favourable meteorological conditions; ©) changing the sprayer configuration; or (d) a combination of the above.

Proposed Approach for Site-Specific Buffer Zones

Under the new approach, the PMRA will continue to calculate buffer zones and specify them on the label according to current practices. The PMRA will also provide the applicator with tables of multipliers which, under specific conditions, can be used to reduce the labelled buffer zone. Although numerous variables affect drift, the PMRA chose those variables believed to be the most important and operationally achievable, in order to simplify the process as much as possible. The variables reflect the sensitive area, meteorology, and equipment specific to the application site. The PMRA also envisions that changes in application technology which will assist in reducing spray drift may also be included by this strategy through periodic updates.

Standard toxicity tests on surrogate species are used to identify habitats which are sensitive to a particular active ingredient. Buffer zones are used to protect sensitive terrestrial and aquatic habitats from spray drift. These habitats vary in their sensitivity and ability to recover from the effects of spray drift; however, few data are available at this time that describe the ability of a habitat to recover from single or multiple exposures to pesticides. Sensitive areas that contain or are comprised of organisms less able to avoid or withstand the impacts of spray drift do not have site-specific multipliers.

Meteorological conditions have significant impacts on spray drift. Applicators are encouraged to minimise particle spray drift through understanding how weather conditions affect drift and applying pesticides only under favourable weather conditions. The meteorological factors known to be the most important in affecting drift are wind speed, temperature, and relative humidity.

The application (sprayer) configuration is under the direct control of the applicator. Applicators are encouraged to minimise pesticide drift through the use of appropriate technology. The application configuration factors known to significantly affect drift, such as spray quality and boom height, and their multipliers are discussed in the following sections.

Sensitive Area Categorisation and Mutlipliers

Due to the wide variability inherent in natural environments, some areas are more sensitive to the effects of particle spray drift than others. Rather than describing and categorising all of the possible areas that may require protection, this proposal attempts to identify the most sensitive components of a particular area. It is the applicator's responsibility to identify the sensitive areas within and adjacent to treated fields.

In general, a sensitive area is considered to be adjacent to a spray area if it is downwind from the treated area and within the (unmodified) labelled buffer zone. An area that is upwind or cross-wind to the treated area or that is not within the downwind labelled buffer zone distance is not considered to be adjacent to the spray area. It is understood that the applicator will ultimately use his or her own judgement when determining those areas in the vicinity of the spray area that require the use of buffer zones.

Sensitive Aquatic Areas

A sensitive aquatic area is defined as any area adjacent to a spray area which consists of any form of water, such as, but not limited to, a lake, pond, stream, river, creek, slough, canal, prairie pothole, or reservoir. Although these habitats are ecologically different, they can be grouped based on broad temporal and spatial similarities.

Aquatic areas may vary over time. Some, such as lakes, are present throughout the season, whereas others, such as sloughs, may be temporary. Consequently, aquatic areas have been divided into two categories based on their temporal nature: permanent and non-permanent.

Assuming a closed system and complete mixing of the water body, the risk to permanent water bodies is determined by the concentration of the pesticide in the water, which itself is a function of the amount of spray drift, the surface area of the water body, and the depth of water. A sensitivity analysis of water depth and surface area, performed using the AGDISP model, indicated that calculated buffer zones are more sensitive to the depth of the water body than its surface area. Decreased pesticide concentrations due to an increased width of the water body are counter-balanced by the increased amount of spray drift deposited to it. Thus, the average depth of the water body was determined to be the most important characteristic of water bodies for calculating buffer zones. In practice, the average depth of the water body will be visually estimated by the applicator and recorded on the application record.

Depth-dependent multipliers for permanent water bodies were determined using the field, airblast and AGDISP models. To determine the appropriate multipliers, buffer zones for different water depths (0.3, 1 and 3 m), spray qualities (Fine, Medium, and Coarse), and toxicological endpoints were calculated. The multipliers were found to be dependent upon the method of application and for aerial application, the spray quality, consequently, the chosen values attempt to encompass the majority of this variation, but not be overly conservative (Table 1). A buffer zone multiplier of 1 was assigned to the basic water depth used in determination of the labelled buffer zone (0.3 m).

Table 1. Site-Specific Multipliers for Permanent Aquatic Areas

Estimated average depth	Multiplier
< 1 m	1
1 - 3 m	0.5
> 3 m	0.3

For temporary and seasonal water bodies, regional differences in water body type and ecological importance prevented a single multiplier from being determined, consequently, Provincial authorities have agreed to provide guidance to applicators for these water bodies.

Sensitive Terrestrial Areas

Terrestrial areas vary widely in their characteristics and there are insufficient data available at this time to group these areas according to their ecological sensitivity to pesticides. Therefore, no additional multipliers are provided to the applicator and the labelled buffer zone distances will apply to all terrestrial areas. The PMRA is, however, consulting with the provinces and territories to determine if a list of excluded terrestrial areas could be included on the label.

Wetlands and Riparian Areas

Wetlands and riparian zones (the area between a defined aquatic and terrestrial area) possess characteristics of both aquatic and terrestrial habitats and may support both aquatic and terrestrial species. These areas are considered to be ecologically important and require protection. The PMRA will determine the appropriate buffer zone for these areas during its risk assessment process; therefore, no additional multipliers are provided to the applicator and the labelled buffer zone distances will apply to all wetlands and riparian areas.

Meteorological and Sprayer Configuration Factors

The best way to prevent spray drift is to spray under good atmospheric conditions with a properly adjusted sprayer. This section focuses on strategies to reduce drift focus based on meteorological conditions and sprayer configuration.

The most important variables affecting spray drift for all application methods are droplet size and wind speed. Other factors (which can be specific to a particular application method) include: atmospheric stability, carrier volume, discharge height and direction, temperature and relative humidity, travel speed, shrouds, adjuvants, and crop canopy conditions. As the inclusion of all possible factors would result in an overwhelmingly complex scheme, only the most important variables were included in this proposal. The major factors affecting drift for specific application methods recognized by this proposal are summarised in Table 2.

Table 2: Major Factors Affecting Spray Drift For Different Application Methods

Application Method	Major Factors
Field Sprayers	Spray quality, wind speed and boom height
Aerial	Spray quality and wind speed
Airblast	Sprayer type and wind speed
Chemigation	Sprinkler type and wind speed

The following is a review of variables affecting drift, with specific reference to four main agricultural application methods: field sprayer, aerial, orchard airblast, and chemigation.

Meteorological Conditions

Wind speed
Wind is an important factor affecting spray drift for all application methods. All other things being constant, airborne spray drift has been found to increase linearly with increasing wind speed for field sprayers (Goering and Butler 1975, Bode *et al.* 1976, Maybank *et al.* 1978, Wolf *et al.* 1993, Grover *et al.* 1997) and non-linearly with increasing wind speed for aerial applications (AGDISP). Very low wind speeds are, however, often very unpredictable in direction, increasing the risk of non-target impact. As a result, spraying is best done when there is some wind, and when the applicator can be sure that wind direction has stabilized. In practice, wind speed is measured at approximately shoulder height using a hand-held anemometer.

The effect of wind speed is a function of several interacting variables. For all application methods, the rate of increase in airborne drift with wind speed decreases with increased droplet size. In other words, coarse sprays are less sensitive to increased wind speeds than fine sprays. For aerial and orchard airblast, where finer sprays are often used, hot and dry conditions may increase the spray's susceptibility to higher wind speed as a result of rapid evaporation to smaller droplet sizes.

Proposal Approach: The proposed scheme reflects the linear nature of the wind speed effect for field sprayers. For all application methods, wind speeds were divided into three categories: 1 to 8 km/h, 9 to16 km/h, and 17 to 25 km/h for field sprayers and chemigation applications and 1 to 5 km/h, 6 to 10 km/h, and 11 to 16 km/h for aerial and airblast applications.

Atmospheric stability
Under normal sunny daytime conditions, the atmosphere is said to be unstable. This means that air near the ground is warmer than air above. Under these conditions, there is considerable thermal turbulence in the atmosphere and adjacent air layers mix readily with each other. If the air contains drift particles, these

are quickly dispersed upward and downward, becoming diluted with clean air which reduces impact. This phenomenon reduces the downwind impact of airborne drift.

The opposite of an unstable atmosphere is a stable atmosphere ("temperature inversion"). Inversions occur when air near the ground is cooler than air above it, typically on nights with limited cloud cover and light to no wind. Under inversion conditions, turbulence is suppressed and suspended spray may hang over the treated area in a concentrated cloud for a long time. Winds after an inversion are very slow and unpredictable in direction, and, when they occur, a concentrated spray drift cloud can be moved off the treated area and cause considerable damage at its destination. For this reason, drift potential is considered high during a temperature inversion despite calm winds. Fine sprays are particularly sensitive to inversion drift.

Proposal Approach: The proposed scheme does not incorporate inversion conditions into drift prediction; instead, a label statement warns applicators to avoid spraying during temperature inversions, regardless of the application method (Goering and Butler 1975, Maybank and Yoshida 1969, Yates and Akesson 1975).

Air temperature and relative humidity
Small water droplets can rapidly evaporate to a smaller size, predisposing themselves to drift. Spray droplets are assumed to evaporate like water droplets because water is the major component of a spray droplet and is much more volatile than the other ingredients. Temperature and relative humidity affect how quickly droplets evaporate. For example, under warm and humid conditions (20ºC and 80% relative humidity), a 100 µm water droplet can evaporate completely in 57 seconds. Under hotter, dry conditions (30ºC and 50% relative humidity), the same droplet can evaporate in 16 seconds. This effect is important for aerial application where finer sprays are used and droplet to target distances are generally > 3 m; however, the interactions of various application factors influence the importance of temperature and humidity.

Proposal Approach: For field sprayers, where discharge heights rarely exceed 1 m, temperature and relative humidity are not considered important enough to be included (Goering and Butler, 1975). An intermediate temperature and relative humidity condition is used for aerial application: 25ºC and 50% RH).

Sprayer Configuration

For all sprayers, drift reducing methods focus on two approaches:

- reducing the proportion of small droplets in the spray cloud (spray quality);
- protecting the spray from wind (boom height and shrouding);

Spray quality
The most effective way to reduce drift potential is to apply coarse sprays that minimize the proportional contribution of small droplets (< 150 µm). Droplet size can be varied in a number of ways, particularly in the selection of a nozzle and spray pressure.

Nozzle Types: Low-drift nozzles use a combination of pressure and flow rate to reduce drift between 50% and 95% from conventional nozzles. Many of these nozzles can be operated at higher pressures without increasing drift potential significantly. This is one of the most important and widely used means of drift reduction for field sprayers. Low-drift nozzles are not widely used in orchard airblast application.

Pressure: For any given nozzle, lower pressures result in coarser sprays. As drift potential can vary by a factor of three within a nozzle's recommended pressure range, the lowest recommended pressure will minimize drift risk. Applicators should always operate within the nozzles' recommended pressure range

Flow Rate: For any given nozzle, a larger orifice (nominal flow rating) will produce a coarser spray. For example, fewer nozzles of higher flow rate on an airblast sprayer will minimize drift. An exception to this rule is high flow rates in fast-moving aircraft (> 140 mph), where air shear of very coarse sprays can reduce droplet size.

Nozzle Fan Angle and Orientation: With most nozzle types, narrower fan angles produce larger droplets. For aerial sprays, orienting nozzles so that the spray is emitted backwards, parallel to the airstream will produce the coarsest droplets. Droplet size decreases as nozzles are oriented more directly into the airstream.

Low-Drift Adjuvants: Low-drift adjuvants increase droplet size for most applications, but some products or product rates may alter deposit patterns.

Proposal Approach: The proposed scheme recognizes that spray nozzle manufacturers typically report the British Crop Protection Council (BCPC) or American Society of Agricultural Engineers (ASAE) spray quality of their nozzles for each flow rating and pressure, and this information is available to applicators (Southcombe *et al.* 1997, ASAE 1999). Spray quality categories in this proposal are: Fine, Medium, and Coarse (aerial application) and Fine, Medium, Coarse, and Very Coarse (field sprayers). Drift potential varies by about a factor of three between adjacent quality classes. Spray quality is considered as a variable for field sprayer and aerial application only. Spray quality adjustments are not common in orchard airblast and chemigation applications.

Boom height and length

Spray can be protected from wind by lowering the boom to its minimum recommended setting: 45 cm for field sprays with 80º fan angles and 35 cm for 110º fan angles. Higher booms may be required to offset boom movement over uneven terrain. By orienting the spray forward or backward, boom height can be reduced as long as the nozzle to target distance is maintained at its minimum recommended in the direction of spray travel.

For aerial sprays, the appropriate boom length is between one third of semi-wingspan (or half of the active rotor length for helicopters) and one half semi-wingspan (Garry Moffatt, personal communication). Boom length should not exceed three quarters of the wing or rotor length as longer booms increase drift potential. When the boom is too low or too wide, ground effect turbulence or wing tip vortices can elevate small droplets, increasing drift.

Orchard airblast sprays should not be directed to exceed the target height. Drift can be further reduced by shutting off the spray between adjacent trees within a row. Tower or tunnel sprayers, which direct the spray horizontally across the foliage or down from on top can help target smaller trees or grapevines more effectively.

Proposal Approach: The proposed scheme assumes that drift potential is increased by a factor of two when the sprayer boom is raised from 0.6 m to 1.2 m for field sprayers (Goering and Butler 1975, Nordby and Skuterud 1975). Although boom height is a very important parameter in aerial applications, it is not considered because flight height decisions are dependent on aircraft size, air speed, terrain, and pilot judgement. For orchard airblast applications, spray discharge direction is considered under "Sprayer types". For chemigation, credit is given for lower boom heights and drop tubes.

Carrier volume
At any given constant travel speed, higher carrier volumes reduce drift only when they are applied with larger flow-rate nozzles which emit coarser sprays. "Twin" nozzles (which can increase nozzle flow rates without an increase in droplet size) would not reduce drift with higher application volumes.

Proposal Approach: In the proposed scheme, no credit will be given for increased carrier volume. In cases where a higher volume is applied with a coarser sprays, this effect will be captured by the spray quality component in the proposal (Maybank *et al.* 1978, Wolf *et al.* 1993)

Travel speed
Faster travel speeds have two main effects on how spray behaves after it leaves the nozzle. First, faster speeds cause emitted spray droplets to stay aloft longer because small droplets are not entrained into the downward flow of larger droplets, but instead descend more slowly at their terminal velocity. Second, faster travel speeds may be accompanied by higher operating pressures, increasing drift potential. The net result is a finer spray that is more exposed to winds. On the other hand, when maintaining a constant carrier volume and pressure, faster travel speeds require the use of larger flow-rate nozzles (= coarser sprays), reducing drift potential. The net effect of travel speed changes to field sprayers are still not clear. For aerial application, higher air speeds usually increase air shear, which increases drift potential. This is most pronounced with highly deflected sprays.

Proposal Approach: In light of the counteracting effects that occur with increasing travel speed, this proposal assumes no net change in drift potential with travel speed.

Shrouds and Cones
In scientific studies, shrouds have been shown to reduced drift by 65% to 85%. Protective cones have been shown to reduce drift by 30% to 50%. An applicator should expect shrouds to become less effective at the higher travel speeds. These technologies are usually only used on tractor-drawn sprayers with low boom heights.

Proposal Approach: The proposed approach allows an additional 30% drift reduction for cones and 70% for shrouds when used at travel speeds < 12 km/h and boom heights < 60 cm (Edwards and Ripper 1953, Maybank *et al.* 1991, Wolf *et al.* 1993).

Crop growth stage
The stage of the crop to be sprayed may have an influence on spray drift. In general, taller, more mature crops contain more foliage that is capable of intercepting droplets that may otherwise drift. This is of particular importance for orchard airblast sprayers.

Proposal Approach: Due to the variable nature of foliation between crops, species, and season, no adjustment will be made for crop growth stage.

Sprayer type
For field sprayers, aerial application, and chemigation applications, the configuration of a sprayer is the sum of the various factors described above. This can result in a large number of possible configurations. For an airblast sprayer, three discrete configurations can be identified. The most common is an axial

blower that generates a radial airblast near ground level and discharges the spray up towards the canopy. Spray from this type of equipment can be very prone to drift if the discharge direction is not well matched to the canopy height or condition. An alternative is a tower or cross-flow blower, where the spray originates from a vertical tower which directs it horizontally or downwards towards the tree or grapevine. For grapes or dwarf trees tunnel sprayers that provide a horizontal discharge direction, completely enclose the plant from two sides, capture, and re-circulate the spray, are available.

Proposal Approach: The proposed guideline allows a 50% drift reduction for tower (cross-flow) sprayers, and a 90% drift reduction for recirculating sprayers (Bäcker and Bleifeld 1994).

Conclusions

The approach outlined in this document is a concept that is being considered by the Pest Management Regulatory Agency (PMRA), Health Canada, and will involve consultation with all stakeholders, which may result in modification of this approach. Buffer zone modifications are based on the best available information from recognized scientific literature or publicly available spray drift models. Buffer Zone multipliers of 1.0 are assigned to the basic sprayer configurations and conditions for which the initial risk assessments were conducted. These multipliers are then revised according to the expected drift risk for other application conditions. For field, orchard, and chemigation application, documented or estimated changes in drift amounts would result in a proportional change in buffer zone (i.e., 50% drift reduction = 50% buffer zone reduction).

Field Sprayers: Buffer zone multipliers for three wind speed ranges (1 to 8, 9 to 16, and 17 to 25 km/h) and four spray qualities (Fine, Medium, Coarse, and Very Coarse) were tabulated for each of two boom heights (< 60 cm and > 60 cm) (Table 3). These tables are used by the applicator to multiply the buffer zone on the pesticide label. For the low boom height field sprayers, additional reduction values were generated for protective cone or shroud equipment.

Orchard Airblast Application: Buffer zone multipliers were tabulated for three sprayer types (axial, cross flow, and recirculating blowers) and three wind speed ranges (1 to 5, 6 to 10, and 11 to 16 km/h) (Table 4).

Chemigation Application: Buffer zone multipliers were tabulated for two boom heights (< 3 m and > 3 m) with a top-mounted high pressure gun, and a low boom height (< 3 m) with a low-pressure sprinkler (drop tubes) for three wind speed ranges (1 to 8, 9 to 16, and 17 to 25 km/h) (Table 5).

Aerial Application: Buffer zone multipliers were tabulated using the AGDISP model for three wind speed ranges (1 to 5, 6 to 10, and 11 to 16 km/h) and three spray qualities (Fine, Medium, and Coarse) (Table 6).

Development of standard label statements to support the proposed approach will be required. The label will include the required buffer zone(s), in a tabulated form, as determined from the risk assessment.

As the approach is too complex for inclusion on a specific pesticide label but is standardized across pesticide labels, the PMRA proposes that the buffer zone modification information be presented in a booklet detailing operation procedures which are known to reduce spray drift (good application practices) and the buffer zone modifier tables. The use of the booklet would also allow efficient updates of the existing tables and the incorporation of multipliers or tables for new proven drift reducing technologies.

Table 3: Buffer Zone Multipliers Used For Field Sprayers

Low Boom (<60 cm)				
Wind Speed (km/h)	**Spray Quality**			
	Fine	**Medium**	**Coarse**	**V. Coarse**
1 to 8	0.8	0.2	0.1	0
9 to 16	1.2	0.6	0.3	0.1
17 to 25	1.6	1	0.6	0.2
High Boom (60-120 cm)				
Wind Speed (km/h)	Spray Quality			
	Fine	**Medium**	**Coarse**	**V. Coarse**
1 to 8	1.6	0.3	0.2	0.1
9 to 16	2.3	1.1	0.6	0.2
17 to 25	3.1	1.9	1.1	0.4
Low Boom, drift-reducing cones				
Wind Speed (km/h)	**Spray Quality**			
	Fine	**Medium**	**Coarse**	**V. Coarse**
1 to 8	0.6	0.1	0.1	0
9 to 16	0.8	0.4	0.2	0.1
17 to 25	1.1	0.7	0.4	0.2
Low Boom, drift reducing shrouds				
Wind Speed (km/h)	**Spray Quality**			
	Fine	**Medium**	**Coarse**	**V. Coarse**
1 to 8	0.2	0.1	0	0
9 to 16	0.4	0.2	0.1	0
17 to 25	0.5	0.3	0.2	0.1

Table 4: Buffer Zone Multipliers Used For Airblast Application

Wind Speed (km/h)	**Spray Quality**		
	Axial Fan, no deflectors	**Cross Flow**	**Tunnel**
1 to 5	0.7	0.2	0.1
6 to 10	1	0.5	0.2
11 to 16	1.3	0.8	0.2

Table 5: Buffer Zone Multipliers Used For Chemigation

Wind Speed (km/h)	Sprinkler Type		
	Top Mounted (> 3 m)	Top Mounted (< 3 m)	Drop Tubes (< 3 m)
1 to 8	0.3	0.1	0
9 to 16	1	0.3	0
17 to 25	3	1	0.1

Table 6: Aerial Buffer Zone Multipliers Based on Labelled Spray Quality

Fine Spray Quality			
Wind Speed (km/h)	**Spray Quality**		
	Fine	**Medium**	**Coarse**
1 to 5	0.4	0.1	0.0
6 to 10	0.7	0.2	0.0
11 to 16	1	0.2	0
Medium Spray Quality			
Wind Speed (km/h)	**Spray Quality**		
	Fine	**Medium**	**Coarse**
1 to 5		**0.3**	0
6 to 10		0.8	0.1
11 to 16		1	0.2
Coarse Spray Quality			
Wind Speed (km/h)	**Spray Quality**		
	Fine	**Medium**	**Coarse**
1 to 5			0.2
6 to 10			0.6
11 to 16			1

There will be no mandatory training requirement; however, to ensure applicator awareness of these changes, it is proposed that implementation be accompanied by activities on several fronts:

1. Inclusion of basic buffer zone information in the “Standard for Pesticide Education, Training and Certification in Canada for Application Technology”. This standard forms the core requirement of provincial certification courses and as such will be available to applicators undergoing certification.

2. Preparation of media articles in popular regional agricultural publications.

3. Participation by provincial and federal regulatory staff in local extension meetings. Such meetings are organized by provincial extension services, grower and commodity groups, or private industry. Standard PowerPoint presentations will be developed as basic training tools.

Although the proposed approach is complex and requires a level of competence on behalf of the applicator, it is more flexible than the current method and allows for buffer zone reductions depending on the type of sensitive area being protected, the application equipment used, and the meteorological conditions at the time of spraying. This 'customization' of buffer zones to the conditions at the time of spraying will also allow applicators to apply pesticides under conditions where the previous 'one size fits all' approach would not have, without increasing the risk to the environment.

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