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ESTABLISHING BUFFERS: PROTOCOLS AND TOXICOLOGICAL BENCHMARKS

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Abstract

One proposed mechanism for protecting both bystanders as well as water bodies from direct exposure to sprays is the use of no-spray buffer zones. Depending on the non-target receptor requiring protection, no-spray zones can encompass an area adjacent to the last tree row or one or more unsprayed tree rows within a field or orchard. The interests of efficient farming and environmental protection must be balanced, so the size of the no-spray zone needs to be protective enough without being so large that farming operations are hindered. One way to achieve this balance is to use drift modeling and integrate the results with toxicologically relevant benchmarks. The model AgDRIFT was used to model downwind deposition of an organophosphorus (OP) insecticide (azinphos-methyl) during an orchard application. Deposition on a surface area basis was changed to a whole body dose, assuming a 10-kg child as the receptor. The EPA-defined acute Reference Dose (RfD) for azinphos-methyl was used as the toxicologically relevant benchmark for defining a very conservative no-spray buffer zone to protect bystanders from an acutely hazardous exposure.

No-Spray Zones: One Solution for Drift Mitigation

The magnitude of spray drift is largely controlled by the physics of particle formation and aerosol movement/deposition. Thus, drift cannot be zero, but it can be minimized, especially by choosing nozzles that are rated to produce aerosols of comparatively high volume median diameters (i.e., coarser sprays). However, sprays must meet the physical characteristics necessary for good foliar coverage and pest control. These requirements are commonly achieved in orchards by use of the airblast sprayer. The airblast sprayer is really a type of air-assisted sprayer because the spray is emitted from nozzles situated along a 180-degree arc and then blown by a high speed fan into the canopy. Velocities of particle movement can reach over 100 mph. The most efficient nozzles for airblast sprayers offer little flexibility in controlling particle size, and the need for forced air movement of the spray makes difficult the minimization of drift.

Air-blast sprayers can attain very good canopy coverage, but the velocity of particle movement also causes movement beyond a single tree row. Thus, at the outer edges of an orchard, spray drift will move off-site. Furthermore, the orientation of the nozzles to reach the upper parts of the tree forces a notable volume of spray above the canopy where it is subject to off-row movement depending on wind direction and speed. Direct exposure of bystanders or workers to orchard spray drift represents an acute but avoidable hazard. One proposed mechanism for protecting both bystanders as well as water bodies from direct entry of sprays is the use of no-spray buffer zones. A no-spray zone, as defined by EPA "is an area in which direct application of the pesticide is prohibited; this area is specified in distance between the closest point of direct pesticide application and the nearest boundary of a site to be protected, unless otherwise specified on a product label" (U.S. EPA 2004)

Depending on the non-target receptor requiring protection, no-spray zones can encompass an area adjacent to the last tree row or one or more unsprayed tree rows within the orchard. The interests of efficient farming and environmental protection must be balanced, so the size of the no-spray zone needs to be protective enough without being so large that farming operations are hindered. One way to achieve this balance is to use drift modeling and integrate the results with toxicologically relevant benchmarks. The end result would be a distance defining the length of a no-spray zone between a swath (or the last row sprayed if in an orchard) and the most sensitive non-target receptor (a human child, a non-target plant, endangered species, aquatic habitat, residential development, etc.).

Using AgDrift for Drift Deposition Modeling

A consortium of agrochemical registrants (known as the Spray Drift Task Force) have developed the model AgDrift. EPA has sanctioned the model for determining off-site movement of chemicals during spraying (Teske et al. 2002). The model estimates downwind deposition following ground, orchard, and aerial applications of pesticides. The ground and orchard modules are based on empirical studies of drift, but the aerial portions, which are applicable to both agricultural and forestry landscapes, rely on a theoretical function for particle movement and particle size distributions for various types of nozzles. The aerial module allows variable meteorological conditions and aircraft parameters to alter the drift deposition results depending on the input of particle size distribution.

AgDRIFT Model output for aerial applications to agricultural crops has been validated in experimental trials. The model predicted reasonably well near-field deposition of spray but was less accurate for far-field deposition (Bird et al. 2002). Measured deposition of helicopter applied sprays (chlorothalonil and endosulfan) in the riparian zone around Christmas tree plantations were reasonably well predicted by AgDRIFT (Felsot et al. 2003), but as shown in other validation studies (Bird et al. 2002), prediction values were very sensitive to relative humidity.

Validations of the orchard module of AgDRIFT for commercial applications have not been published thus far. Spray drift can be simulated from both dormant orchards and orchards with full canopies (Figure 1). The only other input that can be changed in the orchard module is the number of rows sprayed with a maximum of 20.

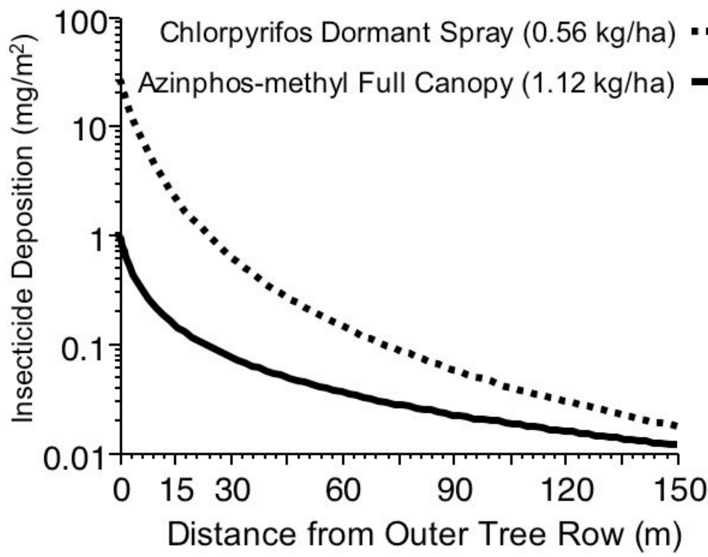

Figure 1. AgDrift simulation of downwind drift deposition of two insecticides from 20 rows of spraying a dormant orchard or an orchard in full canopy.

Choosing Toxicological Benchmarks

Our past work has shown that AgDRIFT modeling output can be overlain with toxicologically relevant benchmarks for predicting the distance between a spray swath and a bystander that would not result in an acute exposure exceeding EPA's standard of a "reasonable certainty of no harm" (Felsot 1999: Felsot 2003). This "reasonable certainty of no harm standard" is described numerically as the

Reference Dose (RfD) and is derived by dividing the No Observable Adverse Effect Level (NOAEL) by an uncertainty (i.e., safety) factor ranging from 100 to 1000. The NOAEL itself is most frequently obtained empirically from single dose (acute), subchronic (90-day) or chronic (2-year) oral exposure studies with rodents. Seven to 21 day dermal exposure studies may also be used. The chosen toxicological endpoints from these studies represent the most sensitive effect.

The most hazardous pesticides used in orchards are the organophosphorus insecticides that inhibit plasma cholinesterase (a.k.a. pseudocholinesterase) and red blood cell and brain acetylcholinesterase. The NOAEL is always based on this endpoint, and thus represents a very sensitive measure of hazard. Occasionally, the doses used in toxicity studies are higher than the NOAEL, so in those cases the LOAEL (Lowest Observable Adverse Effects Level) is used as the toxicological benchmark. The LOAEL is divided by a factor of 300 (or an extra safety factor of 3) to derive the RfD. For example, a rodent acute neurotoxicity study with the most commonly used pome fruit insecticide, azinphos-methyl, resulted in no NOAEL but rather an observed LOAEL of 1 mg/kg. EPA divided the LOAEL by a default factor of 300 to derive the acute RfD of 0.003 mg/kg/day (U.S. EPA, 2001).

Because human exposure to drift is likely to be almost always exclusively by dermal routes, a more realistic endpoint would be the NOAEL from a dermal exposure toxicity study. Alternatively, the maximum permissible exposure (i.e., the exposure equivalent to the oral RfD) could be adjusted upward to account for dermal absorption efficiency. For example, from rodent toxicokinetic studies EPA has concluded that a 42% dermal absorption efficiency can be plausibly used for estimating the potential for human dermal absorption.

Transforming the Units of Deposition (mg/m^2) to the Body Dose (mg/kg/day)

AgDRIFT output is given as a percentage of the active ingredient application rate depositing at various downwind distances. Although the model has a module for predicting residue concentrations in a body of water (pond or flowing), it does not enable automatic prediction of body doses should bystanders be in the area. The body dose can be calculated, however, by assuming that any drifting insecticide will deposit on all or a part of the surface of an exposed person.

The first step is to transform the application rate (kg/ha) to mg/m^2 by multiplying by 100. Multiplying the application rate by the percentage deposition relative to distance will give the proportional deposit per unit area. If we assume that the surface area deposition will be the same on a person as it occurs on a flat surface, and we knew the surface area of a whole person or parts of her body, then we could calculate the exposure as a mass of pesticide per unit body surface area. EPA has assembled the Exposure Factors Handbook (U.S. EPA 1997) that compiles pertinent values for body surface area among tens of other parameters needed to estimate exposures during risk assessments. To be conservative, we can choose the 95th percentile surface area of a 2-year old child, which is 0.682 m^2. The Handbook also gives surface areas for specific body parts, so the exposure estimation could be made more realistic as needed.

The worst-case exposure scenario would assume that the whole body was exposed and dermal absorption into the blood was 100%. More realistic scenarios, however, would adjust the dose by known dermal penetration percentages and an assumption that only the uncovered body parts (head and extremities) are likely to be exposed. If the mass of pesticide depositing on a bystander is divided by the body weight, the units of surface area deposition can be changed to the same units as are used for the NOAEL or RfD (i.e., proportional mg/m^2 depositing at each downwind distance are changed to mg/kg). At each distance, the mg/kg body dose would be reduced by the dermal absorption efficiency. These transformation calculations were applied to a 1.2 kg/ha application rate of azinphos-methyl assuming 20 rows of spraying, a 100% and 42% dermal absorption efficiency, and a child with body weight of 10 kg (Figure 2).

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Estimating the Size of the No-Spray Zone

To obtain a protective no-spray buffer zone, a vertical line is drawn from the body dose corresponding to the RfD to the drift deposition curve (Figure 3). From the point of intersection on the drift deposition curve, the line is dropped to the x-axis and the distance noted. This distance from the spray swath (or last tree row) becomes the width of the no-spray buffer zone, and it represents the distance between the last row sprayed and the deposition of the "safe" dose. For example, the acute RfD for azinphos-methyl (0.003 mg/kg) was overlain on the logarithmically transformed drift deposition curve shown in Figure 2. The no-spray zones corresponded to 21 m and 48 m with assumptions of 42% and 100% dermal absorption efficiency, respectively (Figure 3).

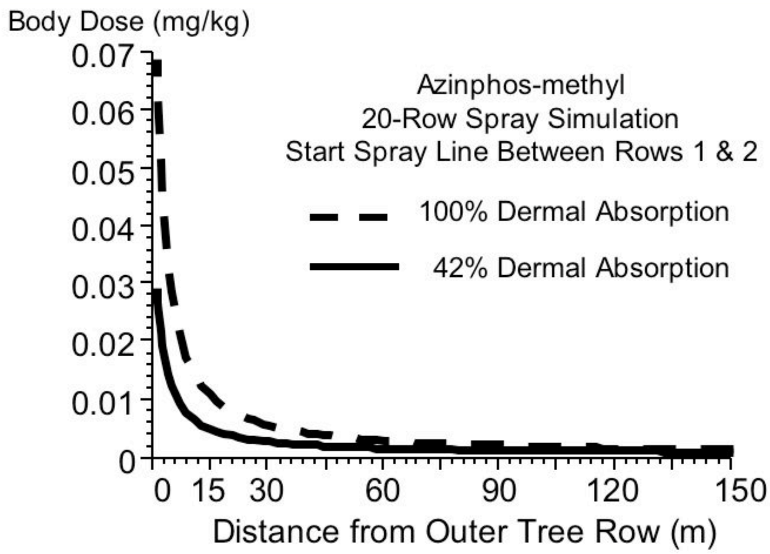

Figure 2. Downwind deposition of azinphos-methyl on a whole body surface area basis transformed to a dosage by dividing by a child body weight of 10 kg.

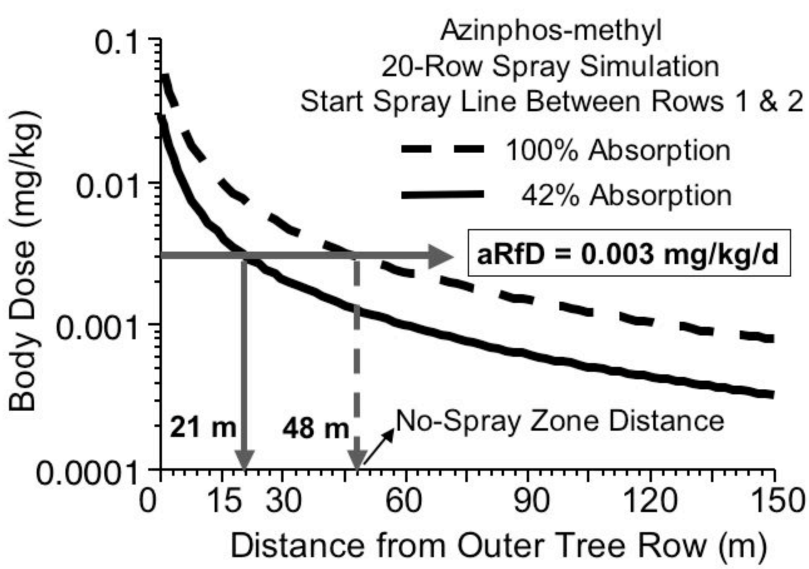

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Figure 3. Estimation of no-spray zones for protection of a 10-kg child according to the standard of "reasonable certainty of no harm". Note that the body dose deposition data were scaled logarithmically to facilitate overlaying the acute reference dose (aRfD) benchmarks.

Persons exposed to any dose lower than the RfD would be considered by EPA to have a reasonable certainty of no harm. Pertinently, the use of the RfD as the toxicological benchmark is quite conservative and favors human health protection because the dose estimated as not causing any harm in rodent studies is adjusted by the sizable uncertainty factor of 100. The size of the no-spray zone can be adjusted to consider more realistic exposure scenarios such as the likelihood that only the arms, hands, legs, and/or face are receptive surface areas.

The described transformation technique has been used to set buffer zones around residential developments that are planned adjacent to orchards in Benton County, Washington. Our current work is attempting to validate AgDRIFT for commercial orchard spraying by determining actual downwind deposition from orchards. If we successfully validate the output from AgDRIFT, then we believe that our method for setting no-spray buffers can be used for individual orchard sites and can be adjusted by specific landscape factors that might influence drift. Matching no-spray zones to specific pesticide use practices and fields/orchards is preferable to setting a "one-size-fits-all" no-spray buffer zone.

References

Bird, S. L., S. G. Perry, S. L. Ray, and M. E. Teske. 2002. Evaluation of the AgDISP aerial spray algorithms in the AgDRIFT model. Environ. Toxicol. Chem. 21(3):672-681.

Felsot, A. S. 1999. Boffo buffer zones. How big is big enough? Agrichemical & Environmental News (November) 163:14-18. (http://aenews.wsu.edu)

Felsot, A. S. 2003. Do buffers make good neighbors? Minimizing pesticide exposure at the ag-urban interface. Agrichemical & Environmental News (July), issue no. 207. 8 pp. http://aenews.wsu.edu/July03AENews/July03AENews.htm

Felsot, A. S., S. Foss, J. Yu. 2003. Deposition of pesticides in riparian buffer zones following aerial applications to Christmas tree plantations. Chapter 14 (pp. 241-260) in Environmental Fate & Effects of Pesticides. J. Coats and H. Yamamoto (Ed.), American Chemical Society Symposium Series 853, Am. Chem. Soc., Washington, DC. (available at http://feql.wsu.edu)

Teske, M. E., S. L. Bird, D. M. Esterly, T. B. Curbishley, S. L. Ray, and S. G. Perry. 2002. AgDRIFT¨: a model for estimating near-field spray drift from aerial applications. Environ. Toxicol. Chem. 21(3):659-671.

U.S. Environmental Protection Agency (EPA). 1997. Exposure Factors Handbook, Volume 1. EPA/600/P-95/002Fa. (available at http://www.epa.gov/ordntrnt/ORD/WebPubs/exposure/)

U.S. Environmental Protection Agency. 2001. Interim Reregistration eligibility decision for azinphos-methyl. Case No. 0235. (available at http://www.epa.gov/oppsrrd1/op/azm.htm)

U.S. Environmental Protection Agency. 2004. Pesticide Registration (PR) Notice 2001-X Draft (Spray and Dust Drift Label Statements for Pesticide Products) http://www.epa.gov/opppmsd1/PR_Notices/prdraft-spraydrift801.htm (updated June 21, 2004).